CERC-BEE Task F2

Advanced Building Technologies and the Role of Energy Efficiency Policies in Promoting their Development and Application

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Disclaimer

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Executive Summary

Building energy consumption can be significantly reduced by the use of today's many advanced technologies that are already developed but yet to be fully commercialized due to the existence of market barriers. Such technologies need the help of carefully designed policies to penetrate the market. Policy interventions are desirable because energy efficiency plays a fundamental role in climate change mitigation. This report first reviews the latest advanced building technologies and building-relevant energy technologies, and then examines the role of government incentives in promoting the development and application of these technologies in the United States and China.

Advanced building technologies

In this report, advanced building technologies are those that enable very low energy buildings and net-zero energy buildings to operate. These buildings can be residential or commercial. Advanced building technologies in this report encompass energy saving design, energy efficient technologies, and distributed energy generation technologies.

Status in the US

Emerging advanced building technologies in the U.S. includes technologies related to building envelope, HVAC, water heating, appliances and consumer electronics, lighting, building controls, distributed energy resources, and integrated building design approach. These commercially available and cost adjusted technologies have made a dramatic impact to the energy efficiency in the U.S whereas barriers for a larger scale implementation still need to be well addressed. The barriers include informational, economic, and regulatory ones.

Policies and related measures, such as codes and standards, labeling, programs etc. have played an important role in effectively promoting the technologies in the US during the past few years, and lots of successful cases were found in this study.

Status in China

China's building energy efficiency market has been developing rapidly over the last decade thanks to the government's strong emphasis on energy conservation. However, China still lags much behind the industrialized countries in the research, development, and adoption of advanced building technologies. Especially it has little experience in the latest technologies, such as advanced windows, advanced power strips, smart meters, demand response, and micro-grids. The types of existing barriers to advanced building technologies are similar to those in the U.S., but the difference is that lacking information and technology ownership is considered the top barrier in China.

Recommendations

The last part of the report provides recommendations for China. A number of key advanced technologies are highlighted to Chinese policy makers for the great contributions these technologies can potential make in building energy conservation and for their technical maturity. Such technologies include cool roof, ground source heat pump, LED lighting, power strip, advanced energy management system, demand response for buildings, and integrated building design. To overcome the market barriers that these technologies currently face, China can:

- design supportive polices based on the market diffusion theory, i.e. to target different technologies according to and adjusting by their development stages and market potentials;
- update building energy standards periodically with higher quantitative targets to help the deployment of very low energy buildings;
- diversify current incentive schemes to support various stakeholders, such as design institutes, builders, developers, building operators, and consumers;
- step up efforts in information sharing and information transparency with regard to building energy consumptions, advanced building technology applications, and energy efficiency services.

Introduction

Advanced building technologies are technologies that enable very low energy buildings and net zero energy buildings in the residential or commercial building sectors. Advanced building technologies encompass energy saving design, energy efficient technologies, and distributed energy generation technologies. Advanced technologies are available in the market, but normally they cost higher than conventional technologies.

The main research questions of this report are 1) what are the main barriers for advanced building technologies to enter the U.S. and Chinese markets; and 2) what policies and programs have been introduced to overcome those barriers in the two countries?

This report begins with examining the U.S. situation first in Part I and China's situation in Part II. In each of these chapters, we cover the advanced building technologies in each of the following major groupings:

1. Building envelope
2. Heating, ventilation, and air conditioning
3. Water heating
4. Appliances and plug loads
5. Lighting
6. Building controls, metering, and communication
7. Distributed energy resources
8. Integrated design

Our emphasis is not on individual technologies, but rather on the practice of integrated design. Very low energy buildings and net-zero energy buildings can only be realized when systems are integrated and optimized in a way that allows synergistic benefits and deeper energy savings to be realized. The goal of promoting the use of advanced technologies is to design a building with a high level of performance (in comfort and energy efficiency) and a cost that is similar or lower to buildings designed under a systems approach.

In each of the chapters, we analyze the common informational, economic, and regulatory barriers to advanced building technology development and deployment. In most cases, there has been some proposed policy or program to try and overcome these various barriers, often by 'pushing' the technologies into the marketplace with additional financial incentives. We place these policies and barriers in the larger context of the entire building energy efficiency policy space, including codes, standards, and labeling, which covers more mature technologies. The idea here is that, although they are currently only at initial research and demonstrations stages, advanced building technologies will eventually begin to mature while costs decline and market saturation will subsequently grow. At that stage, policies such as codes and labeling will be needed to continue 'pulling' these technologies into the market.

In Part III, based on the previous review of U.S. and Chinese situations, we present some recommendations for China on policy enhancement to support the development and commercialization of advanced building technologies.

Annex I tabulates the barriers to advanced building technologies in the United States and China, respectively. Annex II presents a few specific U.S. and Chinese cases of utilizing advanced building technologies.

Part I. Advanced Building Technologies and Related Policies in the United States

Advanced building technologies

The following sections will outline what advanced building technologies are available or emerging in each major building system including envelope; heating, ventilation, and air conditioning (HVAC); water heating; appliances and plug loads; lighting; building controls, metering, and communication; and distributed energy resources. Each technology will be described to highlight its energy saving advantages and common applications.

Building Envelope

The building envelope primarily consists of window, roof, and insulation technologies. The building envelope is responsible for about 25 percent of all building energy use in the U.S., but it can impact up to 42 percent of residential building use and 57 percent of commercial building use in real world through better day-lighting techniques, smarter windows, improved insulation, and associated efficiency gains in heating and cooling (smaller system size). As will be discussed later in the integrated design section, the design of a buildings envelope system has key implications for the sizing and technology choice in HVAC and lighting systems. Advanced building technologies in the building envelope system include cool roofs, advanced windows, and interior and exterior shading systems.

Cool roofs

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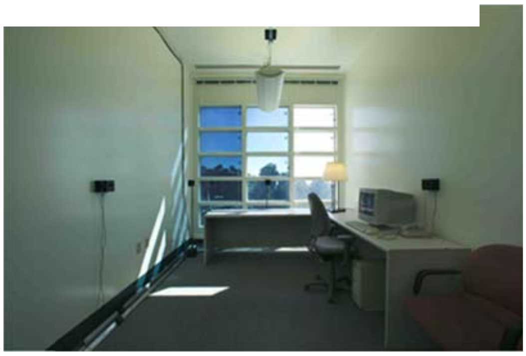
Cool roofs are roofs that stay cool under solar exposure by minimizing solar absorption and maximizing thermal emission through the application of paints, coatings, or colorings. By minimizing solar absorption, the flow of heat from the roof into the building decreases the need for space cooling energy in air-conditioned buildings. Often, there is a small heating penalty due to lost heating gain from the sun in the winter.

The most common applications are in warm and hot climate regions that have long cooling seasons and short heating seasons. Energy savings measurements on cool roof applications have been taken in such climates in the U.S. including California, Florida, and Texas. Typically summertime air conditioning and peak demand reductions ranged between 10 percent and 30 percent, although values as low as 2 percent and as high 40 percent were reported. One recent study found that retrofitting 80 percent of the 2.58 billion square meters of commercial building conditioned roof area in the U.S. would yield an annual cooling energy saving of 10.4 TWh, an annual heating energy penalty of 133 million therms (much less than the cooling energy savings), and an annual energy cost saving of $735 million (Levinson and Akbari 2010).

Advanced windows

The first category of advanced windows typically includes windows that have low heat transfer coefficients (U-value) and thus good insulation properties; and also low solar heat gain coefficients. These low U-values are usually achieved through various glazing techniques, particularly the use of low-emissivity coatings. The second category of advanced windows are those that have 'smart' functionality and can change transparency, light transmission, and solar heat gain factor. These smart windows include electrochromic and thermotropic varieties. Both categories of windows are often used to reduce solar heat gain in warmer climates and in turn reduce cooling energy use and peak loads. Note that the latter category is not really commercially available yet.



Low U-value windows have the highest "R-value"; they are inversely related. The U.S. Department of Energy (DOE) defines windows with high-performance glazing as those windows with a U-value of 0.2. Common double pane windows are U-0.5, while ENERGY STAR windows are R-0.3. Moving from U-0.3 to U-0.2 can reduce average heat loss by 30 percent. The glazing techniques used in U-0.2 windows usually involved spectrally selective coatings, which filter out 40-70 percent of the heat transmitted through clear glass while still allowing the full amount of light to be transmitted.

According to the Green Proving Ground (GPG) program, these windows can have a price premium of $43 per square meter but prove to be cost effective in several climate zones on the basis of energy savings alone. Additional savings can be garnered from a downsized HVAC capacity. GPG reports: "The technology is particularly applicable to commercial new construction and major reconstruction that have high window-to-wall area ratios that are fully conditioned and where the capital cost can be offset by the downsized HVAC equipment cost." The GPG program has also researched the application of a clear, water-based, spray-on coating for retrofitting existing buildings which it is currently testing its use and impact on energy use in federal buildings.

Manufacturers claim heating and cooling savings between 20-40 percent and a payback time of 2-4 years.

In the smart windows category, there are electrochromic and thermotropic varieties which can both dynamically change light transmission and solar heat gain factor. The thermotropic window has organic polymers embedded in the glass which automatically darken and lighten based on the surface temperature of the window. The electrochromic window (shown in Figure 2) can vary its tinting between 2 percent and 60 percent via an electronic control (which could be altered by the occupant for his own comfort) and thus requires an external power source that can be integrated into the window frame. This electronic functionality may incur additional operations and maintenance costs. The GPG reports: “Preliminary data show that this emerging technology can reduce overall cooling loads by up to 20 percent. Additionally, the dynamic nature of this glazing may improve the performance of daylight harvesting luminaires, yielding additional energy savings…The technology is most applicable to new construction and major reconstruction where the capital cost can be offset by the downsized HVAC equipment cost. On a retrofit basis, this technology may be more difficult to justify on a cost/benefit basis.” (Kandt and Lowell 2012)

Interior and exterior shading systems

Interior and exterior shading systems have significant technical potential due to their low cost and applicability for both new and retrofit construction. LBNL recently undertook a study at its Windows Tested Facility, which “enables accurate quantification of energy use, peak demand, and occupant comfort impacts of synergistic facade-lighting-HVAC systems on an apples-to-apples comparative basis”. Several types of shading systems were tested on the same south facing façade in temperate Berkeley over a six-month period. Options include Venetian vs. roller blinds, manual vs. automated operation, and interior vs. exterior application. While interior systems may be lower cost and easier to implement, especially in interior applications, exterior systems can offer a significant degree of solar control and will likely be an application that can enable very low energy buildings. LBNL reports: “Coupling exterior shading systems with moderate to large-area transparent windows seems counter-intuitive: one can achieve the same reduction in thermal loads by simply downsizing the window and selecting a window with a low solar heat gain coefficient and U-value. Use of exterior shading systems, however, can enable use of daylight to offset lighting energy requirements and can be a near-term solution for overall very low energy use in both commercial and residential buildings.” As can be seen in

Table 1, both manual and automated exterior shade systems achieved very high levels of both lighting energy savings and cooling load savings. (Lee, et al. 2009)

TABLE 1: MONITORED PERFORMANCE OF INNOVATIVE SHADING SYSTEMS AT LBNL (LEE, ET AL. 2009)

		Interior Shades		Exterior Shades	
		Manual	**Automated**	**Manual**	**Automated**
Lighting energy use	kWh/ft^2-yr	1.04-1.13	0.92-1.11	1.12-1.41	1.0-1.27
Lighting energy savings	percent	62-65 percent	62-69 percent	53-63 percent	58-67 percent
Cooling load savings	percent	Up to 15 percent	Up to 22 percent	78-94 percent	80-87 percent
Peak cooling load	W/ft^2-floor	8.0-9.4	8.0-9.8	1.6-3.1	2.0-2.5
Avg time uncomfortable	Hours/day	2.3-3.7	0.0-1.1	0.7-3.8	0.2-3.0

Heating, Ventilation, and Air Conditioning

Heating, ventilation, and air conditioning (HVAC) end uses typically account for 34 percent of commercial building energy use. Although the energy efficiency of many HVAC components has substantially improved over the past 40 years, there is still a need to make systems as a whole more efficient. For example, data suggest that air leakage from thermal distribution systems in commercial buildings is common and increases HVAC energy consumption by 10-40 percent. Better system diagnostics and analysis tools are needed to support both efficient HVAC design and operation.

In this section, we will review a selection of advanced HVAC technologies and modifications that can provide significant energy savings while maintaining occupant comfort levels, including chilled beams cooling, commercial energy recovery ventilation systems, variable refrigerant flow, and condensing boilers. Additionally, HVAC strategies that take increased advantage of the natural environment and renewable resources, including natural ventilation and ground source heat pumps, will be described.

Chilled beams cooling

Chilled beam cooling relies on the use of water as opposed to air for cooling in order to achieve enhanced energy efficiency. Instead of fans to move air, pumps move water. Pumping water is inherently more efficient than pumping air. As such, Chilled beams cooling systems are reported to have energy savings in the range of 10-30 percent when compared to baseline variable air volume chilled water systems. Although there is often a small upfront cost premium, project energy and O&M savings (fewer fans, filters, and air-handling units) lead to favorable payback periods. Chilled beams also have the co-benefits of being quieter than variable air volume air conditioning and improving occupant satisfaction. Moreover, simplified mechanical design enables reduced mechanical room space. There are some drawbacks. Chilled beams (an example is shown in Figure 3)) often require complete reconfiguration of mechanical and ceiling systems and are therefore usually just applied to new construction or very major renovation projects. (Sachs, Lin and Lowenberger 2009).

Commercial energy recovery ventilation systems

Since codes in the U.S. often require outdoor air to be introduced for mechanically ventilated commercial buildings, that outdoor air often needs to be tempered if it is very hot, cold, or humid. Energy recovery ventilation systems can be applied to exchange heat between outgoing exhaust air and ventilation air being brought in. Their application can be difficult where ventilation exhaust and intake ducts are located far apart from each other. If applied properly, the application of this technology can save energy up to 10 percent and reduce the capacity of the HVAC system. The federal government has mandated that all federal buildings use such systems, and applications are growing across the U.S. through utility programs that sponsor the use of this technology. (Sachs, Lin and Lowenberger 2009)

Variable refrigerant flow

Variable refrigerant flow (VRF) air conditioning uses modular air conditioning equipment applicable to a wide variety of facilities as an alternative to unitary air conditioning equipment. One outdoor condensing unit is connected to multiple indoor evaporators, which can each be controlled individually so that VRF units only work at the needed rate. Refrigerant is used as the cooling medium and the amount of refrigerator being sent to each evaporator is modulated as needed. GPG reports: "Heat recovery VRF technology allows individual indoor units to heat or cool as required, while the compressor load benefits from the internal heat recovery. Energy savings of 15 percent to 55 percent are predicted over comparable unitary equipment.one major source of savings is much less fan energy because refrigerant transfers by far the most heat per unit transport energy. This product is new to the North American market, and most HVAC designers and installers are not familiar with the technology, but is common in Asia and growing in the EU. Current estimates show an initial cost 20 to 40 percent higher than a traditional split/heat pump HVAC system, but with a payback that should be life cycle cost effective." (Kandt and Lowell 2012)

Natural ventilation

Mechanical cooling and fan energy use account for approximately 20 percent of commercial building electrical consumption in the United States Natural ventilation is the process of providing ventilation – and potentially cooling services as well – without the use of a mechanical system. The natural forces of wind and buoyancy are used to deliver fresh air to a building. While many buildings cannot have natural ventilation alone without some more of air conditioning, the concept of integrating passive natural ventilation in conventional air-conditioned buildings has received increasing attention. In fact, such systems have been used in the United Kingdom over the past 20 years.

Although buildings with only natural ventilation and no air-conditioning exist, they are rare. The most common approach is a mixed-mode approach with one of the following operational strategies:

1) alternating operation allows either the mechanical or the natural ventilation system to operate at one time;
2) changeover operation allows either or both systems to operate on a seasonal or daily basis depending on the outdoor air temperature, time of day, occupancy,

user command, etc. -- the system adapts to the most effective ventilation solution for the current conditions;

3) concurrent operation where both systems operate in the same space at the same time (e.g., mechanical ventilation that has operable windows). (E. Lee n.d.)

Some of the best applications in the U.S. are in commercial buildings in coastal California, Oregon, and Washington where the climate is moderate and outdoor air is very clean. These buildings can take advantage of natural ventilation for passive cooling thus reducing the need for conventional HVAC systems. The California Academy of Science in Golden Gate Park in San Francisco uses a combination of green roofing and skylights as its natural ventilation strategy. The steep slopes of the roof act as a natural ventilation system, while the skylights automatically open on warm days to vent hot air from the building.

Ground source heat pumps

Ground source heat pump (GSHP), also known as geothermal heat pump, is a mature technology and its application has been rapidly increasing in many countries since the mid-1990s (Navigant Consulting 2009). The global installed capacity of GSHP was 1,900 megawatt thermal (MWt) in 1990, increased to 5,300 MWt in 2000, and 15,400 MWt by 2005 (Navigant Consulting 2009). By 2010, the world's total installed capacity reached 50,583 MWt; and the United States and China ranked number one and two in the world, respectively reached 12,611 MWt and 8,898 MWt (Tomarov and Shipkov 2010).

However, the current level of geothermal utilization is only a fraction of the huge extractable geothermal energy that the Earth can provide us. For example, China's installed GSHP capacity in 2010, as mentioned above, probably replaced 2.6 million tons of standard coal in that year, while the amount of utilizable geothermal energy for space cooling and heating at shallow depths was estimated at about 350 million tons of standard coal per year in 2011 (Chandrasekharam n.d.).

GSHP uses the earth as a heat source in the winter and as a heat sink in the summer, taking advantage of the moderate temperatures in the ground to reduce the operational costs of heating and cooling. The vertical borehole heat exchanger is the most common GSHP application in the U.S. whereby a number of large boreholes are drilled deep (typically 150-200 feet, or 45-60 meters) into the earth.

Even though the installation price of a geothermal system can be several times that of an air-source system of the same heating and cooling capacity, the additional costs are returned in energy savings in 5 to 10 years. System life is estimated at 25 years for inside components and more than 50 years for the ground loop. Still, high first costs remain a barrier as do lack of consumer knowledge and trust for GSHP systems. A number of programs in the U.S. have aimed at increasing GSHP applications, particularly the Federal Energy Management Program whereby many U.S. federal agencies (especially the Department of Defense) took advantage of small grants to explore and implement GSHP systems on their sites.

ES GSHP
DEMAND

Water Heating

Water heating accounts for 9 percent of all building energy use in the U.S., though that percentage is only around 7 percent in commercial buildings while it is 12 percent in residential buildings. Water-heating efficiency has increased over time in both electric and gas applications, but there is still room for improvement of gas applications with a number of advanced, high efficiency water heating applications such as heat pump water heaters and condensing water heat recovery devices.. Additionally, solar water heating remains a cost effective use of renewable resources to heat water.

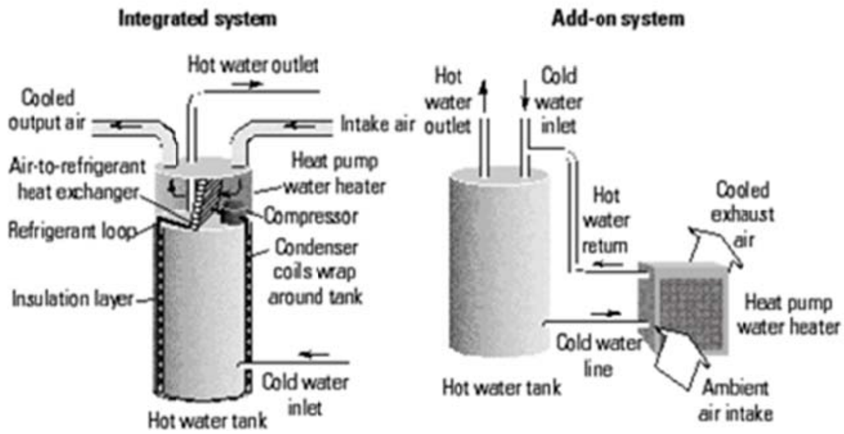
Heat pump water heaters

The U.S. market is dominated by storage or tank water heaters, with roughly equal market shares for electric resistance and gas heat sources. Heat pump water heaters (HPWH) fall into the electric category but to date are a vanishingly small market share, although new DOE standards may change that for the larger units. A good HPWH will use less than half as much electricity for the same amount of hot water. HPWH use a vapor compression refrigeration cycle to concentrate ambient heat. They also dehumidify and cool the air in space in which they are installed, which is an attractive attribute for humid climates. Both 'drop-in' models for replacements and 'add-on' models for retrofit exist in the HPWH market; some simple schematics can be seen in

VATER

. From 2015, the U.S. Department of Energy will require HPWH units for all electric water heaters with a capacity greater than 55 gallons (208 liters). This requirement will likely grow incrementally to include smaller capacity units. (Sachs, Talbot and Kaufman 2011)

WATER



Condensing water heat recovery devices

Condensing gas appliances are inherently 10 percent more efficient than non-condensing ones because they capture latent heat released when steam condenses into liquid water. Actually, efficiency gains can be much higher (up to 39 percent) due to system design synergies, but the units are more costly

than their non-condensing counterparts. Previous use was restricted to high-water use facilities like hotels and laundries, but now the residential market is expanding. (Sachs, Talbot and Kaufman 2011)

Solar water heating systems

Using the sun to heat water through rooftop or ground mounted solar water heating (SWH) systems is usually cost-effective, with average system cost in the U.S. ranging from $2,000 to $4,000. The best applications are for larger families that use large amounts of hot water; geographically speaking, lower latitudes and sunnier climates are best. SWH's usually needs a backup water heater. Passive SWH do not use any energy and simply use solar energy and gravity to circulate water between the storage tank and the collector, where the water heats up. As water in the collector heats, the hotter water rises into a storage tank placed slightly above the collector; while cooler water runs down to replace it. Active SWH have a pump to move water from the collector to the storage tank.

As solar photovoltaic (PV) become cheaper, roof space is often being used in favor of PV over SWH due to higher cost savings, although some utilities around the U.S. still promote SWH.

A new advanced technology will combine PV and SWH. Normal roof mounted photovoltaic panels are paired with thermal heat extractor panels mounted beneath them, thereby collecting both electric and thermal energy from the same footprint. One company called Naked Energy is also pursuing this idea with a unique tubular PV product, seen in Figure 7. Since reducing the temperature of a PV panel increases its average efficiency, the overall energy gains could be quite substantial. (Kandt and Lowell 2012)

Appliances and consumer electronics

Plug-loads account for approximately 25 percent of the total load in a minimally code-compliant office building. As very low energy buildings and net-zero energy buildings apply large system efficiencies to HVAC, envelope, and lighting systems, plug loads will account for a much larger proportion of the building's energy footprint (potentially more than 50 percent), so applications will be needed to make more efficient appliances and consumer electronics.

EPPY

Advanced power strips

Advanced power strips (APS) are one application for commercial buildings to apply to workspaces and common office areas such as kitchens and printer/copier rooms. A recent study by the General Services Administration and NREL selected eight buildings for piloting APS (where plug loads averaged 21 percent of the buildings' energy footprints). Twelve APS replaced standard power strips in each building, with a number of plug-load reduction strategies including schedule timer control, load-sensing control, and a combination of the two. Schedule timers allowed the user to set the day and time when a circuit will be shut on and off. The study reports: "Results underscored the effectiveness of schedule-based functionality, which reduced plug loads at workstations by 26 percent, even though advanced computer power management was already in place and nearly 50 percent in printer rooms and kitchens. The simple payback period for schedule timers was less than 8 years in all applications: kitchens, 0.7 years; printer rooms, 1.1 years; and miscellaneous devices, 4.1 years. Even in workstations, where power management was in place, payback was 7.8 years. Occupant surveys revealed that the majority of users did not wish to have more control over their individual APSs. However, they were willing to program power strips to reflect their personal work schedules. Users also wanted an easily accessible manual override." (Metzger, Cutler and Sheppy 2012)

Smart appliances

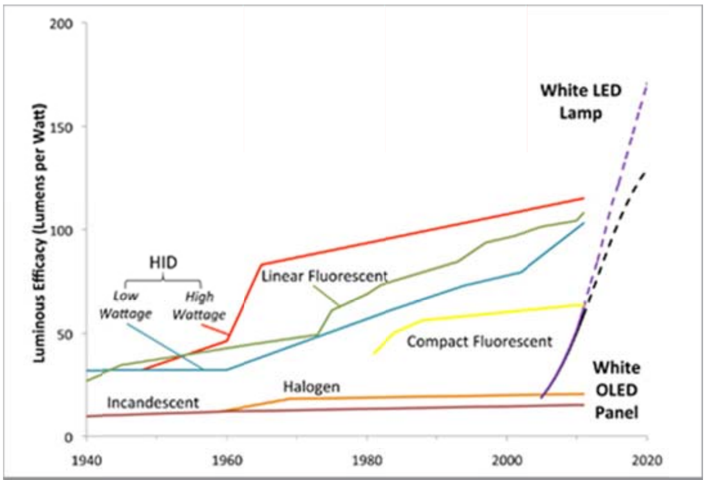
Smart appliances are starting to emerge on the market as well in the U.S. Manufacturers and utilities have a great interest in integrating smart meter and demand response functionality into individual appliances. These functions may not lead to large site energy savings, but could lead to reductions in peak demand and associated source energy savings. Delay load capabilities and spinning reserve capabilities as applied to refrigerators, clothes washers and dryers, dishwashers, and air conditioning have all been proven. Now, standards are being set to introduce these new functionalities into the marketplace. (Messner and Nadel 2011)

Lighting

Lighting accounts for 38 percent of the electricity used by commercial buildings in the United States and 39 percent of electricity use in office buildings, representing a large potential source of energy savings. While linear and compact fluorescent (CFL) bulbs and fixtures have offered large savings over incandescent and halogen bulbs, solid state lighting technology such as light emitting diodes (LED) are now pushing the future in efficient lighting, as seen in **Error! Reference source not found.**. LEDs are more costly than CFLs at the moment although costs will come down over time. In the meantime, many utilities are offering subsidies and rebates for LEDs.

FIGURE 9: EFFICACY POTENTIALS FOR SOLID STATE LIGHTING TECHNOLOGIES

source: DOE SSL R&D Multi-Year Program Plan



While traditional lighting technologies are relatively mature and offer less potential for improvement, SSL is still at a comparatively early stage and continues to achieve dramatic advances in efficacy.

Beyond new efficient lighting technologies, the majority of savings can be found in lighting design and lighting controls (such as daylighting controls and occupancy sensors). Designing for proper daylighting is described in the envelope and integrated building design sections. Daylighting controls can help easily dim lights up and down according to how much light is let in via windows. Occupancy sensors are relatively commonplace now and have short payback periods of half a year to a couple years.

Building controls

Building controls, as defined by an expert report by the Pacific Northwest National Laboratory, can be broken down into the following energy-related functionalities (see **Error! Reference source not found.**): plant control, plant maintenance, energy saving, recording, and communication (fire safety, security, etc. are in a different category not addressed here). With the onset of digital technologies and the smart grid, many new building control technologies have emerged. Additionally, most building systems now seek to use some form of building controls to deliver their service. For instance, occupancy sensors are becoming more and more prevalent for lighting systems. This section will describe some advanced building control technologies, including energy management control systems, wireless pneumatic thermostats, advanced metering infrastructure (smart meters), and demand response.

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Building control functionality	Examples

Plant control	Space temperature control, boiler sequencing
Plant maintenance	Fault reporting/alarming, equipment “run-time” monitoring
Energy saving	HVAC/lighting scheduling, occupancy sensors, building night purge
Recording	Energy metering, energy use monitoring
Communication	Smart meter, demand response

It should first be noted that building controls with energy-related functionalities (lighting, HVAC) usually also have a very high impact on occupant comfort and productivity as well. In office buildings, it has been estimated that a 2 percent increase in the occupant productivity has the same financial impact as eliminating all building maintenance and energy expenditures. Table 3 shows the breakdown of annual expenditures for a typical small office building. Given this fact, all increases in energy efficiency should be designed to improve occupant comfort and productivity. If they investments in efficiency also happen to improve comfort and productivity, then the building owner is much more likely to make the investment.

Expenditure	**Annual cost, $/ft^2**
Office workers’ salaries	130.00
Gross office rent	21.00
Total energy use	1.81
Repair and maintenance	1.37

TABLE 3: BREAKDOWN OF TYPICAL SMALL OFFICE BUILDING ANNUAL EXPENDITURES (BRAMBLEY, ET AL. 2005)

Total building operations and management salaries	0.58

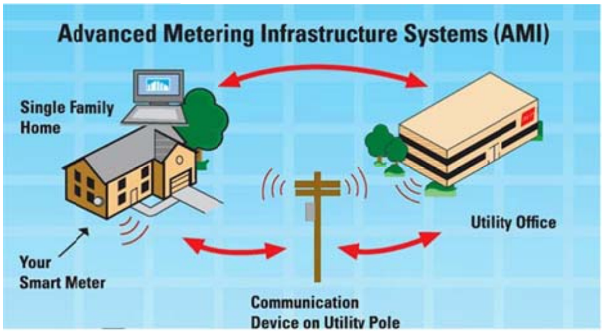
Energy management control systems

A study conducted in 1999 (Commercial Building Energy Consumption Survey or CBECS) showed that only 33 percent of commercial building floor space and only 10 percent of all commercial buildings employed energy management control systems (EMCSs) with more advanced control approaches having an even smaller market share. Nevertheless, this was an 80 percent increase from the 1995 version of CBECS due to computerization of building functions, expanded functionality and user friendliness of control systems, and price decreases. More recent analog data is not available, but increased use is likely with increasing ease and decreasing cost of computation and internet capabilities. However, even if there has been an increase in EMCS use, many building operators appear to use only a fraction of available EMCS functionality and, hence, do not realize all potential energy savings.

Advanced metering infrastructure (smart meters)

Advanced metering infrastructure interfaces utilities (or other energy providers) and their customers in residential and commercial buildings, providing critical links for such services as automated demand response. It is seen as a critical part of the future smart grid. Smart meters, being deployed in homes and office buildings in the U.S., measure real-time energy use in time intervals of one hour or less. Unlike previous automatic meter reading, smart meters are enabled for two way communication. Smart meters, unlike other advanced building technologies, have been installed by the utility as opposed to the home owner or building owner, in part because smart meters enable utilities to roll out time of use pricing.

UCTURE



Demand response

Demand response (DR) consists of changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized. Buildings that have the ability to control their HVAC, lighting, and other energy loads should have the ability to participate in demand response, given the added functionality of advanced metering infrastructure. Price signals can be sent in real-time to the meter of a building or home and users can adjust their usage manually or automatically. For a large group of buildings (a campus for instance), that customer might have an incentive to set up its own demand response automation server (see **Error! Reference source not found.**), such that it can respond to real-time price signals from the utility and adjust its loads accordingly to save money, while helping the utility reduce peak loads when system reliability is at risk.

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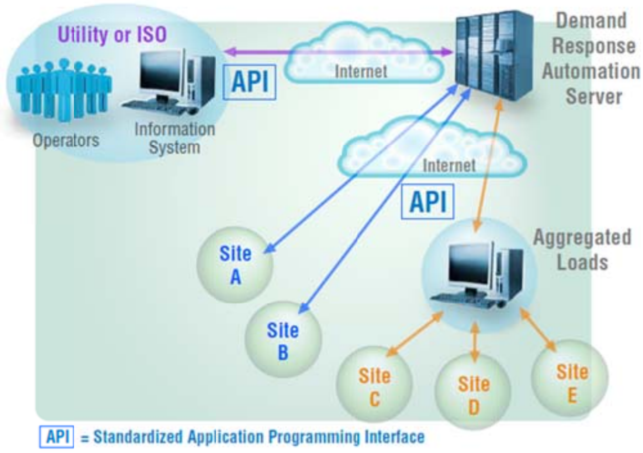
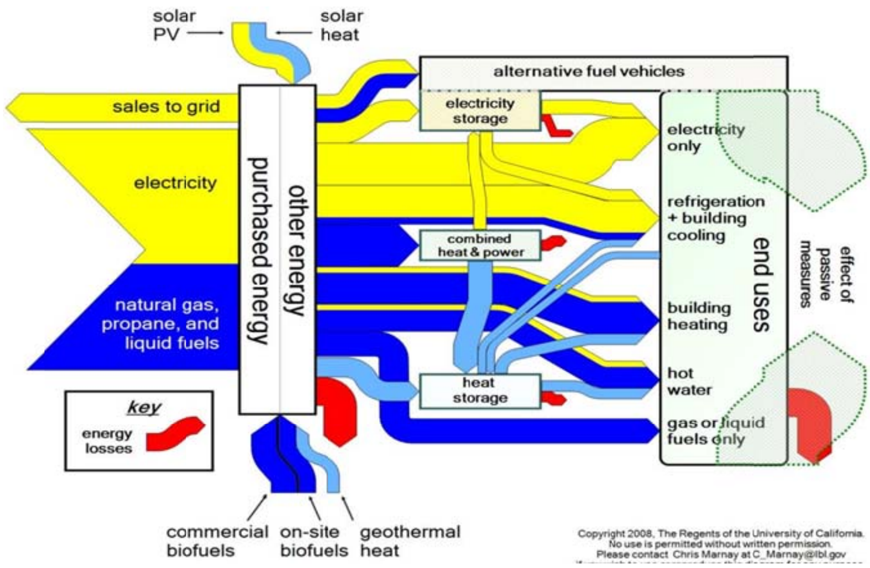


Distributed energy resources

Commercial building customers are increasingly interested in improving their energy efficiency and reliability while lowering costs and environmental footprint. The electricity supply industry is concerned about increasing or simply maintaining reliability while serving a growing load and meeting clean energy mandates while containing costs. Governments are driving renewable or clean energy adoption in the interests of climate change mitigation, energy security, and other environmental goals. The interests of the customer, technology provider, utility, and government stakeholders in a new grid paradigm are profound and have the common threads of cost, reliability, efficiency, clean energy, and climate change mitigation.

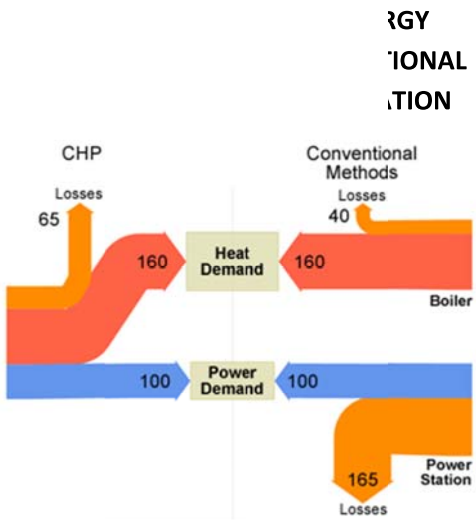
Many countries and regions around the world have looked to distributed energy resources (DER) and microgrids often as part of smart grid initiatives to address these challenges. Governments have enacted policies to increase the share of clean energy and DER. However, the interconnection of DER to the conventional network brings technical challenges that threaten reliability or compromise safety. Microgrids are an enabler of increased distributed generation by creating an electrical ecosystem more amenable to small-scale grid unfriendly resources. Some of the most commonly used DER technologies and microgrids can pull together DER, demand response, and storage technologies to enable a suite of energy efficiency, renewable energy, and cost savings opportunities. (Romankiewicz, et al. 2012)

If a commercial or large residential building is looking into its own DER, the most important step is to first analyze its needs in terms of the following categories: electricity, refrigeration and building cooling, building heating, hot water, fuels and other uses. From there, an ideal energy supply can be formed according to cost, reliability, carbon footprint, or other parameters.



Combined heat and power

Combined heat and power (CHP) equipment is designed to produce power from fossil or biofuels into electricity and use the waste heat from the conversion process either directly or to produce more power through turbines. Facilities with high heating chillers will typically prove to be appropriate for CHP installation from a purely economic standpoint, but warmer regions with high cooling loads can also contain good sites for combined cooling, heating, and power (CCHP). Absorption technologies on the demand-side can be installed to utilize waste heat meeting cooling or refrigeration loads. While inefficient relative to standard electrical cooling, these absorption technologies could be feasible since they use waste heat from CHPs and they are becoming increasingly common, especially in warm or hot climate zones.



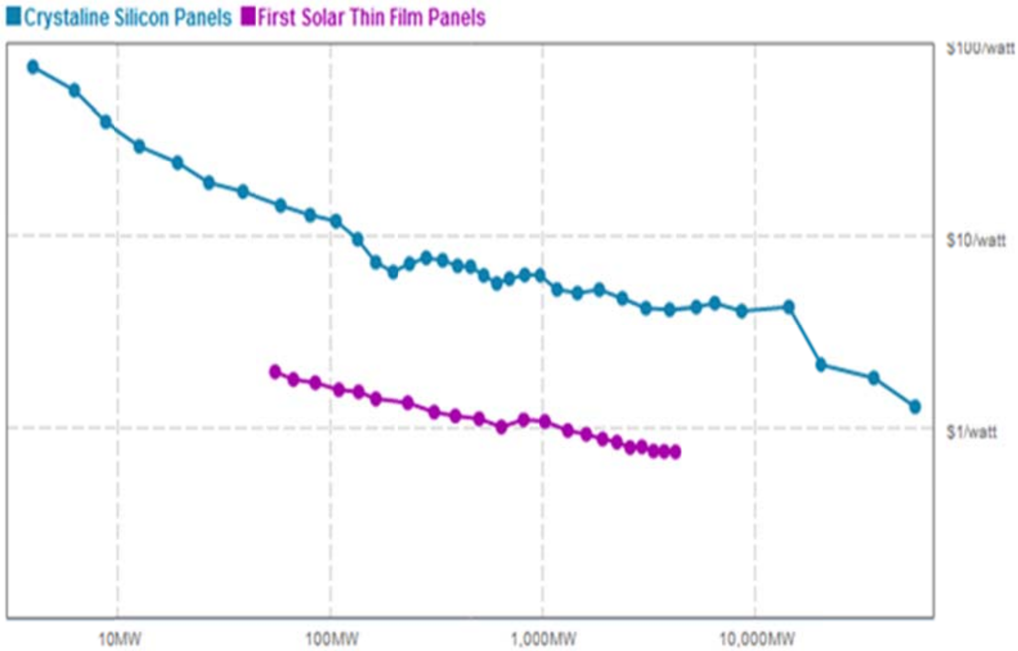
Analysis has shown that medium-size commercial buildings (with peak electric loads ranging from 100 kW to 5 MW) are often good sites for distributed generation with CHP. Figure 13 shows the comparatively small amount of energy losses in a CHP system as compared to conventional generation which has huge heat loses at the power station. (Romankiewicz, et al. 2012)

Fuel cells and microturbines
Fuel cells utilize the chemical energy of fuel to generate electricity without combustion. The process is inherently efficient and environmentally clean, with electrical efficiencies between 40 and 60 percent, depending on the type. When the waste heat is captured in a CHP configuration, overall energy efficiency can be 85 percent or higher. Fuel cell applications have grown steadily in recent years, with Bloom Energy being the most notable company in the space; their “Bloom Box” is shown in Figure 14.

Microturbines are small combustion turbines that produce between 25 kW and 500 kW of power. Microturbines have several advantages such as small size, light weight, and low maintenance costs. Nonetheless, they do release combustion product emissions, and high first cost in part because of their complex power electronics remains another drawback to their use. Both fuel cells and microturbines can run on a range of fuels including natural gas and biogas. (Romankiewicz, et al. 2012)

Solar photovoltaic
Solar energy utilization refers to the use of solar radiation for various social needs. Although most renewable energy are directly come from or derived from solar energy, two solar energy applications are most common in urban energy system – PV and solar thermal.

According to Bloomberg New Energy Finance, the cost of crystalline silicon solar modules has fallen by 24 percent on average for every doubling in installed capacity, while the cost of thin films modules has fallen by 12 percent for every doubling (see Figure 15). Rooftop solar PV applications are rapidly approaching “grid parity” in many regions around the world (Roston 2012).



Energy storage

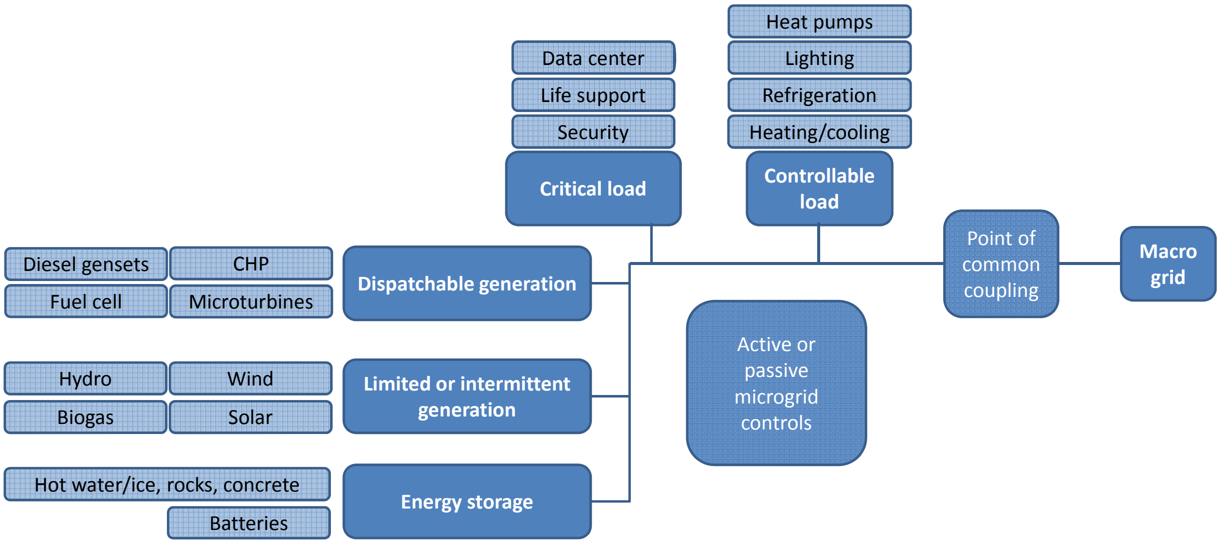
Electrical energy storage can help buildings ensure power balance despite fluctuations in demand and supply. It can also be used for tariff arbitrage by purchasing electricity when it is cheapest and storing it for use during expensive periods. Further cost reductions and increased lifetime and cycles in battery technologies are needed before widespread applications can occur. Another Bloomberg New Energy Finance study noted that grid-scale lithium-ion battery projects today cost more than $1,000/kWh, but given manufacturing oversupply in the short term, costs are expected to drop over the next three years to $600/kWh by 2015. Batteries in electric vehicle may also be opportunities for microgrids in the future, and as sales pickup further price drops are expected there as well. Current costs stand around $800-1000/kWh and battery costs are expected to hit $350/kWh by 2020, according to Bloomberg's study (Zindler 2011). While Li-ion batteries are the

expected battery of choice for electric vehicles, many other storage options are used at the building and grid level, including lead-acid, nickel-cadmium, sodium-sulfur, sodium-nickel-chloride, vanadium redox, and zinc-bromine batteries; double layered capacitors and super-capacitors; and flywheels.

Microgrids

Figure 17 displays the components most readily seen in microgrid demonstrations currently. There are both loads and generation sources. Within loads, there may be critical loads which require high or perfect reliability and cannot lose power, such as a security system at a prison or a life support system at a hospital. There may also be controllable loads which either require lower reliability or whose time of service may be rescheduled without unjustifiably reducing service quality, such as heating, cooling, or refrigeration. Within generation, there are sources which are dispatchable, such fuel cells, or microturbines, possibly in CHP systems. Heat pumps (air, water, or ground source) can often function continuously. Many renewable sources have limited or no dispatch ability, such as wind and solar, while others can be dispatchable, such as hydropower or biogas. Energy storage is often incorporated into microgrids as a way to deal with intermittency or to take advantage of pricing structures for grid power. Thermal storage in hot materials, water, or ice can also capture arbitrage opportunities. Lastly, there are the microgrid controls, which could range widely in sophistication across different applications. In addition to microgrid variability in availability and cost of supply, fluctuation in loads also creates technical challenges. Small power systems generally have greater load variation, a phenomenon that makes control and storage particularly crucial to microgrids.

FIGURE 17: OVERVIEW OF THE MAIN COMPONENTS IN A COMMON MICROGRID, ADAPTED FROM SIEMENS 2011



In commercial buildings in the U.S., space and water heating, air-conditioning, and refrigeration account for 58 percent of energy consumption on average, while lighting and office equipment account for another 24 percent on average. Given this breakdown, microgrids can function most efficiently when taking into account all opportunities for savings in heating and cooling, particularly in the use of any waste heat generated from on-site power generation. While clean energy technologies such as solar PV and wind are seen as the leaders of the clean energy revolution, fuel cells with CHP functionality, reciprocating engine gensets, or microturbines with heat exchangers can often realize much more impressive energy savings and CO2 emissions reductions.

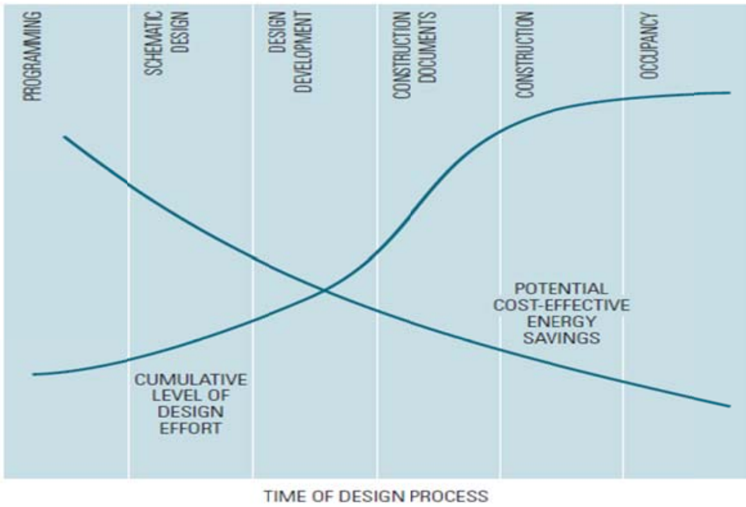
Integrated building design: en route to very low and net zero energy buildings

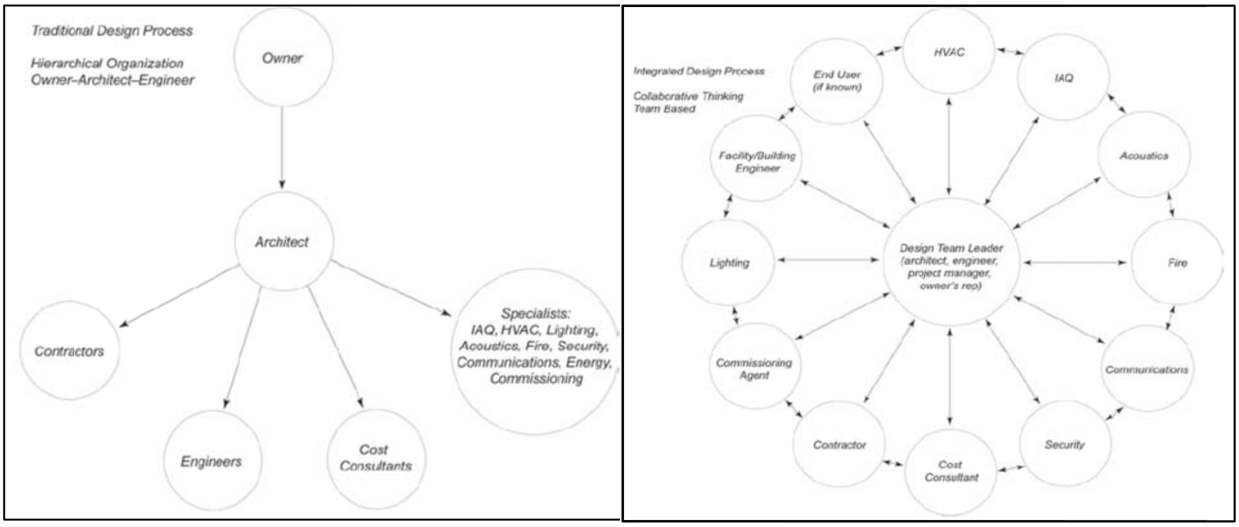
Integrated building design is a critical step on the path to very low energy and net-zero energy buildings for a number of reasons. First, when building systems are designed together to function as one unit rather than designed separately, the energy footprint of the building will be much lower. This is especially true in the case of interaction between the HVAC, lighting, and envelope systems. For instance, a well-insulated envelope that incorporates day-lighting as well as exterior shading technologies can be operated to both minimize HVAC and lighting loads, meaning lower cost HVAC systems that also may take up less space and be simpler to design and control. For some buildings, heating and cooling may not be needed at all, saving immense capital costs. Second, many advanced building technologies require newer building controls in order to realize full efficiency potential and to improve occupants' satisfaction. Real-time feedback and monitoring is needed to optimize building operations, occupants comfort, and energy efficiency. Integrated building design can both harness efficiency synergies between systems and design processes to ensure that information on those systems is consistently collected and used for optimizing building operations.

A recent report on integrated building design was written by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), American Institute of Architects, Illuminating Engineering Society of North America, U.S. Green Building Council, and U.S. Department of Energy. It outlined how integrated design can lead to building energy footprint that is 50 percent below the ASHRAE 90.1-2004 standard with the following eight essential steps:

1. Obtain building owner buy-in.
2. Assemble an experienced, innovative design team.
3. Adopt an integrated design process.
4. Consider a daylighting consultant.
5. Consider energy modeling.
6. Use building commissioning.
7. Train building users and operations staff.
8. Monitor the building.

Figure 18 hows how important it is to design a building properly from the start, as potential cost-effective energy savings opportunities decrease rapidly once design processes are in motion. **Error! Reference source not found.** shows how different traditional building design and integrated building design teams are.





Barriers to advanced building technologies

Barriers for the development and successful implementation of advanced building technologies include informational, economic, and regulatory barriers. The barriers reviewed in this report are outlined below and in Appendix 1. The table has associated information on what technologies typically face this barrier, what policy solutions exist, and if there is related case study examples whereby a solution was used to overcome a barrier and successfully implement a technology.

1. Informational:
    - Fragmented design and decision making process
    - Incomplete and imperfect information needed for decision making
    - Unfamiliarity of architects, engineers, and building operators with new tech/products;
    - lack of tools for simulating technology performance; lack of performance data thus new technologies often perceived as risky
    - high cost of using current building simulation tools to facilitate integrated design
2. Economic:
    - Lack of financing or access to credit; inability to capitalize energy savings
    - Lack of cost recovery mechanisms
    - Split incentives
3. Regulatory:
    - Interconnection charges for distributed generation
    - Lack of compensation for power/services sold
    - No incentive for some lower emission technologies

Informational barriers

Fragmented design and decision making process: The decision-making process is complex and fragmented by numerous players whose interests may not align, including investors, owners, occupants, builders, architects, etc.

Incomplete and imperfect information needed for decision making: Information about energy-efficient building technologies is often incomplete, unavailable, expensive, and difficult to obtain. The complexity of design, construction, and operation of buildings makes it difficult to characterize the extent that any particular building is energy efficient.

Unfamiliarity of architects, engineers, and building operators with new tech/products; lack of performance data thus new technologies often perceived as risky; lack of tools for simulating technology performance: Architects and engineers will often decline to use new technologies they are not familiar with or have not used before due to increased risk for their project and their clients. If advanced building technologies are chosen, then they need to be properly installed, commissioned, and operated, but building operators have no way of becoming familiar with these new technologies. New technologies often have insufficient validation of their performance outside of the laboratory. Additionally, there is a lack of tools to simulate the performance of a new technology and its interaction with other systems.

Economic barriers

High first cost of advanced technologies and designs: Building owners and investors are often reluctant to pay more upfront to purchase products with lower life cycle costs. Investment in energy efficiency measures also competes directly with funds that could be invested in other core business functions. VELB or ZEB incorporating integrating design generally cost more to design and build due to greater system integration and the need for more building controls and measurement points.

Lack of financing or access to credit: Businesses may have trouble finding financing for energy efficiency upgrades, since energy cost savings are generally not considered in the property valuation and financing.

Lack of cost-recovery mechanisms: Lack of cost-recovery mechanisms for energy efficiency investments hinders many electric utilities from promoting such technologies.

Split incentives: Landlords and builders often do not invest in energy efficiency in new construction, as well as in building renovations and upgrades, because tenants and homebuyers receive the benefits of lower energy bills.

Regulatory barriers

Interconnection charges for distributed generation: Utilities have historically been unfriendly to the development of distributed generation, imposing complex procedures and often costly fees for interconnection.

Lack of compensation for power/services sold: Often residential and commercial buildings that have distributed energy resources installed on site can export net power to the grid. Many commercial buildings also have the ability to provide demand response services by shifting heating, cooling, and other loads. Some utilities do not provide any way of compensating power sold or demand response services provided, decreasing the economic incentives for building owners to invest in these technologies.

No incentive for some lower emissions technologies: Solar PV is a very popular investment as an advanced building technology because of its public visibility and popularity. A CHP system, however, may not have any incentives.

Policies that promote advanced building technologies

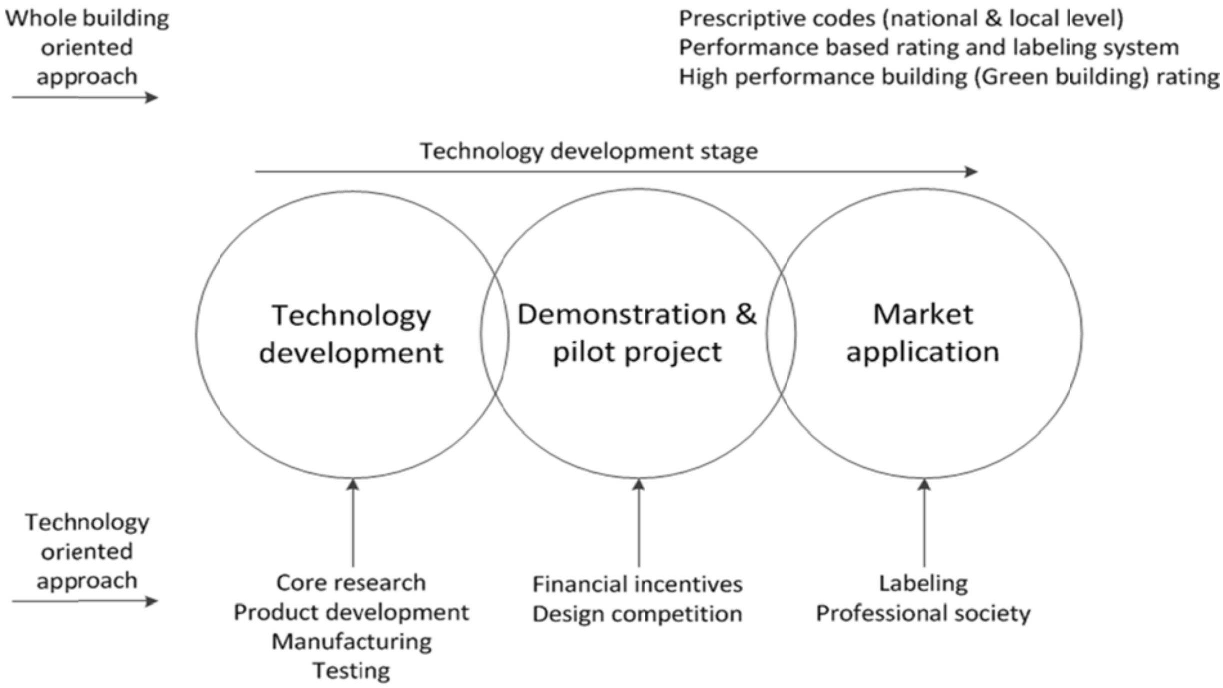
This section is broken down into two parts:

1) an overview of the role targets, standards, and voluntary/mandatory labeling will play in the development very low energy and net-zero energy buildings
2) an overview of state (California's Savings by Design) and federal (FEMP, Green Proving Ground, Solid State Lighting program) programs that address the highlighted barriers for advanced building technologies

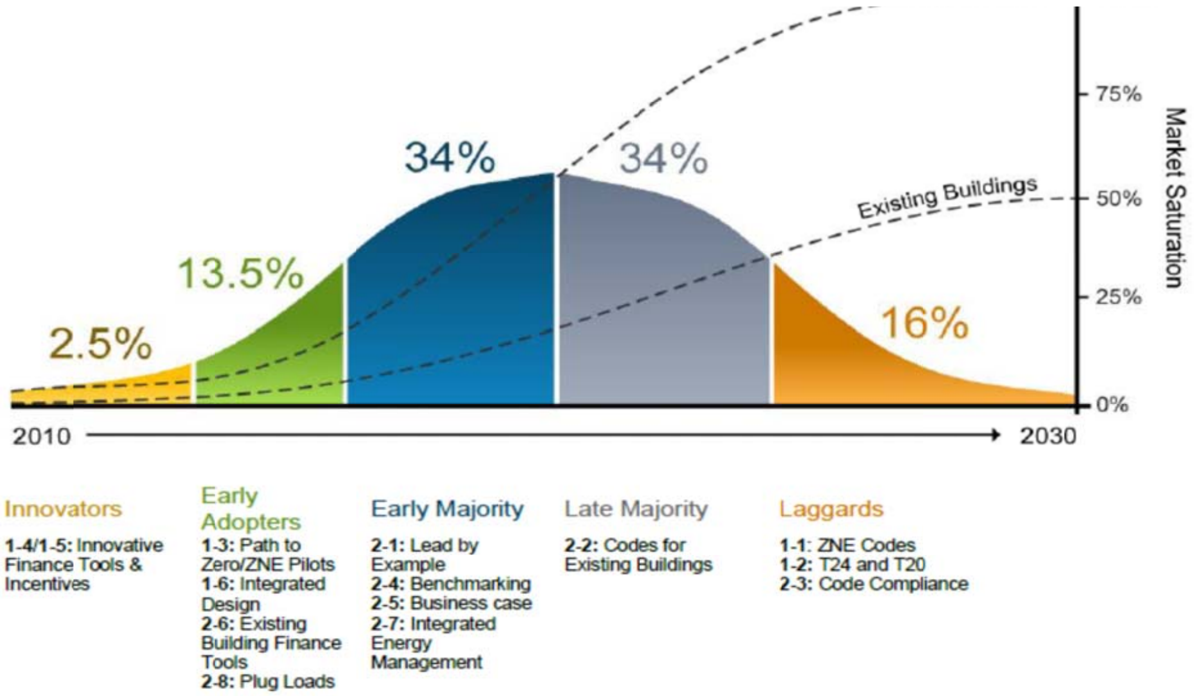
The role of targets, standards, and voluntary/mandatory labeling

First, we would like to address the difference between whole building approaches and technology specific approaches. Additionally, we would like to emphasize that it makes no sense to “push” advanced technologies (innovators, early adopters) with R&D money, financial incentives, and demonstrations if there is no policy to “pull” those technologies into the market later with targets, codes, and performance based labeling. **Error! Reference source not found.** below outlines what policies are used to promote technologies at each stage, and highlights how codes and labeling can be applied at the whole building approach for when technologies mature and reach the stage of market deployment.

TO



California is leading the way with its net zero energy building goals. The California Public Utilities Commission (CPUC) created a strategic plan calling for, among other energy-efficiency goals, net-zero-energy commercial buildings by 2030 and net-zero-energy residential construction by 2020. At the federal level, Executive Order 13514 is mandating that all new federal government buildings will need to be net zero energy by 2030. Meanwhile the City of Austin, Texas has perhaps the most aggressive goal in the country: All new residential construction will need to be net zero energy capable by 2015. A home is zero-energy capable when it is energy-efficient enough to achieve net-zero energy consumption over the course of the year with the addition of on-site renewables. The City of Austin defines a net-zero capable home as a single-family home that is 65 percent more energy-efficient than a typical home built to the Austin Energy Code in 2006.



California has put out a strategic plan for hitting its low-energy and zero net energy (ZNE) buildings, described in the market diffusion chart in **Error! Reference source not found.**. The graph above shows how the market will transform to ZNE between now and the year 2030, when 100 percent of newly constructed buildings will be zero net energy and 50 percent of existing buildings will be retrofit to zero net energy, as code requirements reach that level.

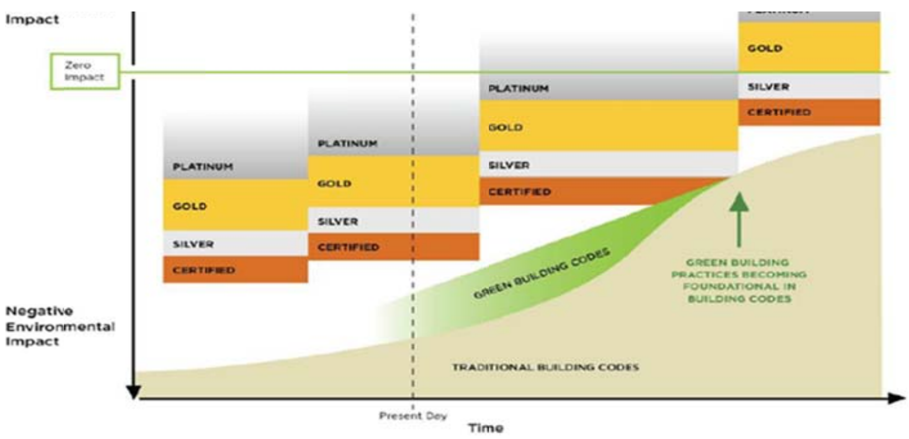
- *Innovators* (the first 2.5 percent of the market): reach zero net energy with their buildings in the next few years
- *Early adopters* (13.5 percent of the market) reach ZNE levels of performance on average in the latter half of the decade

- *Early Majority* (34 percent of the market): driven by benchmarking, retro-commissioning, behavior and energy management strategies, and will ramp up deep energy savings approaching 2020 and beyond
- *Late majority* (34 percent of the market): utilize existing codes and build off finance and energy management innovations in the previous time segment
- *Laggards* (the last 16 percent): Utility programs and reach codes will continue to stay ahead of Title 24 and codes, but realizing that over the entire time period, it is these efforts combined that will drive the mass of the market to zero in the final few years before 2030.

The Strategic Plan created multiple pathways leading to zero energy over the next 20 years, including (ZNE-Stakeholders 2010):

- Codes, with an increase in energy efficiency every three years
- Utility programs (including Savings By Design) and local advanced/reach codes with results that will influence the majority of commercial square footage in California
- Early adopter buildings that are striving for the higher levels of green building rating systems and may also be supported by IOU ZNE pilots
- Innovators, the leaders among practitioners and the private sector, who have already delivered a series of ZNE highly efficient buildings, and work with utility and national zero energy programs to use the most advanced designs and technology

Voluntary labeling schemes will continue to push the envelope for very low energy and net-zero energy buildings, as shown below in **Error! Reference source not found.**.



Overview of state and federal programs that address barriers for advanced building technologies

California: Savings by Design

Savings by Design is a statewide program in California that encourages high performance commercial building design and construction. It is sponsored by California's four investor-owned utilities and offers building owners, investors, and design teams the following basic services:

- Design assistance: provide analysis and information
- Owner incentives: assist owners with any higher upfront investment costs for energy efficient building technologies
- Design team incentives: rewards for design teams that meet assigned energy efficiency targets
- Energy design resources: toolbox and resources to help facilitate integrated design of VELB and ZNE buildings

The rest of this section on Savings by Design is quoted from Savings by Design website: http://www.savingsbydesign.com

Design team incentives

Financial incentives are available to design teams who make the extra effort when integrating energy efficiency with exceptional design. The design team may qualify for incentives when the building design saves at least 10 percent and the owner agrees to participate in the program. Other incentives for design teams are available. Contact your utility representative early in the design process to see which options meet your needs.

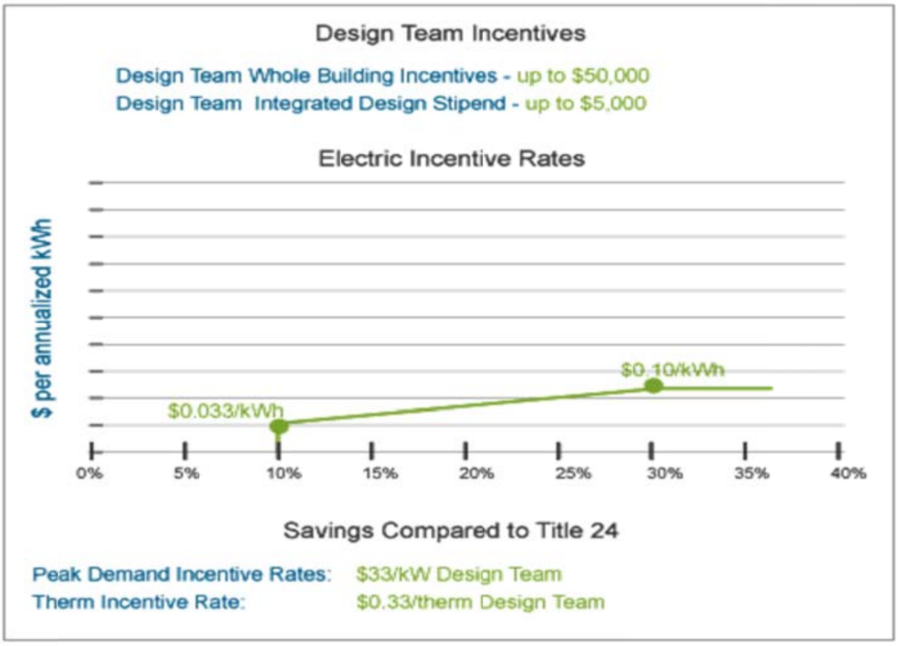
To encourage owners to invest in energy efficiency as a major goal in their new buildings, financial incentives are available to owners when the efficiency of their new building exceeds the minimum Savings by Design threshold (generally 10 percent better than Title 24 Energy Efficiency Standards).

Savings by Design encourages a team approach to the design of energy efficient buildings. By working together to integrate the systems within a building, the design team can more effectively design efficient facilities that may qualify for Design Team Incentives. Encouraging teams to explore these higher levels of energy efficiency, these incentives help offset some of the added costs resulting from investigating enhanced options, and promotes energy efficient features in a new construction projects. To qualify for Design Team Incentives, the team uses the Whole Building Approach and a computer simulation model to optimize their design.

- The model calculates the energy savings of the building compared to the Title 24 baseline.
- The Design Team qualifies for incentives when the building design saves at least 10 percent.
- Design Team incentives range from $0.033 - $0.10 per annualized kWh savings and $0.333 per annualized therm savings as the design becomes more efficient.
- The maximum incentive per project is $50,000.

The Design Team will submit a summary report of one qualifying proposed integrated design.

- Projects exceeding Title 24 by at least 10 percent will receive Design Team Incentives upon construction completion and verification.
- Design teams submitting projects that perform at least 30 percent better than Title 24 are now eligible to receive 50 percent of the incentive upon utility acceptance of the proposed design.
- The balance of the incentive will be paid upon construction completion and verification.



Owner incentives

To encourage owners to invest in energy efficiency as a major goal in their new buildings, financial incentives are available to owners when the efficiency of their new building exceeds the minimum Savings by Design threshold (generally 10 percent better than Title 24 Energy Efficiency Standards).

Whole Building Approach

The Whole Building Approach is the preferred method of achieving energy savings within Savings By Design. Enabling the design team to consider integrated energy efficiency solutions that balance electric and gas use, may lead to buildings that offer:

- Greater health, comfort, and productivity for the occupant
- Reduced building and operating costs for the owner

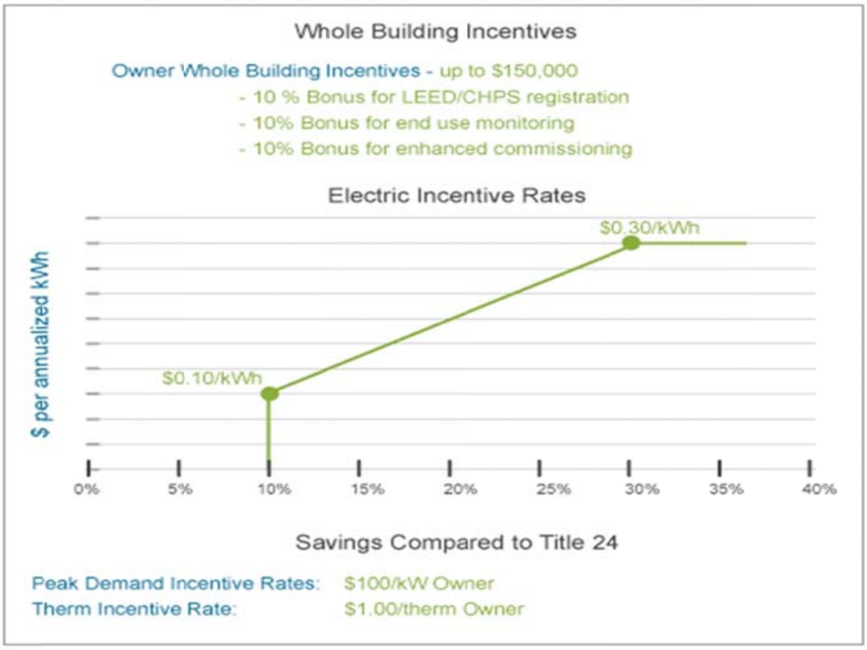
In the Whole Building Approach, the estimated total annual energy savings for the building is calculated compared to the Title 24 minimum requirements. Using an approved computer modeling tool, this analysis can be prepared by the design team, or by an energy consultant provided by the utility. The modeling tools are the same one as those used in the performance based code compliance. This brought feasibility and convenience to customers and program administrators due to the fact that performance modeling is automated to a large extent and gives repeatable results. This same software can be the basis of labels and ratings that allow capitalization of energy efficiency and therefore can get around all of the first cost and financing barriers we discussed before.

Owner's Incentives are available for projects estimated to exceed Title 24 or standard practice baseline by at least 10 percent on a whole building performance basis. Owner Incentives range from $0.10 - $0.30 per annualized kWh savings and $1.00 per annualized thermal savings as the design becomes more efficient.

Owners meeting program requirements may be eligible to receive additional incentives:

- Enhanced Commissioning Incentive
- Certification Incentive
- End Use Monitoring Incentive

Each incentive is calculated as 10 percent of the Owner's Incentive. The maximum incentive per project is $150,000.



Systems Approach

The Systems Approach is a method of optimizing energy efficiency choices for less complex buildings. By considering building systems holistically rather than as a collection of components, the Systems Approach encourages greater energy efficiency by designing “whole” building systems, rather than individual equipment or fixtures. It’s a straightforward approach, and the Design Team may find it more appropriate for their project. Your Savings by Design Representative can help by:

- Using a simplified energy simulation modeling tool to help your team identify system options and quickly estimate the associated potential savings
- Identifying which systems qualify for potential Owner Incentives

Systems Approach Project Incentives are calculated using a flat incentive rate. Your Savings by Design representative can help you identify system options, quickly estimate the associated potential savings, and identify which systems qualify for generous incentives:

- Daylighting
- Interior Lighting
- Heating, Ventilation, and Air Conditioning
- Service Hot Water
- Other Systems and Processes

Daylighting Systems

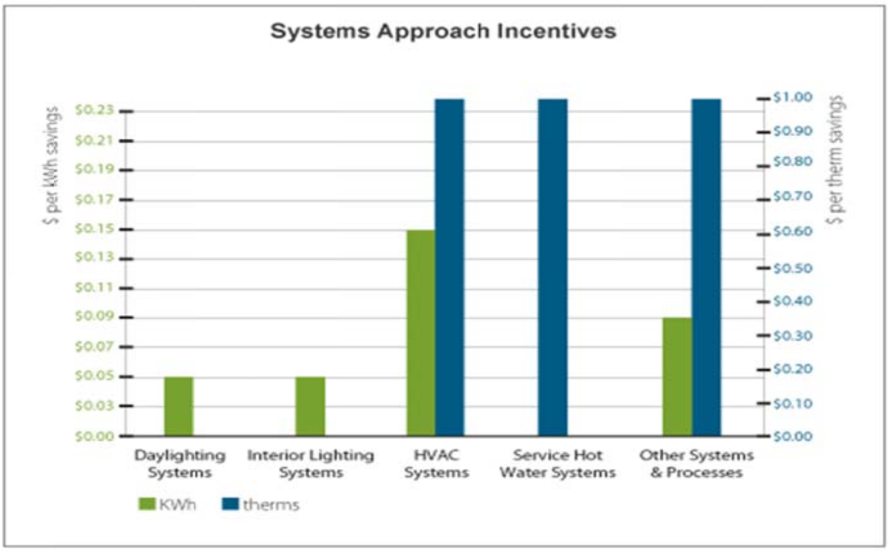
Daylighting has a major impact on a building's functionality from many perspectives. Not only does it decrease energy costs associated with illumination and space conditioning, it also enhances the building's comfort and ambiance -- resulting in increased productivity of its occupants.

Interior Lighting Systems
Interior lighting is a major component of any building's energy use, enhancing the functionality of interior spaces. Energy usage can be reduced with thoughtful attention to illumination requirements within the building, along with specifications for efficient components and appropriate controls.

Heating, Ventilation, and Air Conditioning Systems
The design of high-performance HVAC systems includes high-efficiency equipment and controls that regulate the system to allow operation only when it's needed. Thoughtful consideration of the interactions of all system elements can substantially increase comfort for building occupants while cutting costs for the building owner.

Service Hot Water Systems
The use of high-efficiency natural gas hot water heaters can help to round out an overall approach to energy savings in the building design. Facilities that use large amounts of hot water can see substantial savings when a high-efficiency system is used.

Other Systems and Processes
A variety of process systems and controls not regulated by Title 24 can be considered for the Savings By Design program. Current industry practice is used to establish a reference point from which estimated energy savings are determined for manufacturing, refrigeration, food processing, mechanical ventilation systems and other systems and processes.



Federal: Green Proving Ground
Quoted from (Kandt and Lowell 2012)

"The federal government's General Services Administration's (GSA) Public Buildings Service (PBS) acquires space on behalf of the federal government through new construction and leasing, and acts as a caretaker for federal properties across the country. PBS owns or leases 9,624 assets and maintains an inventory of more than 370.2 million square feet of workspace, and as such has enormous potential for implementing energy efficient and renewable energy technologies to reduce energy and water use and associated emissions.1

The Green Proving Ground (GPG) program utilizes GSA's real estate portfolio to test and evaluate innovative and underutilized sustainable building technologies and practices. Findings are used to support the development of GSA performance specifications and inform decision making within GSA, other federal agencies, and the real estate industry. The program aims to drive innovation in environmental performance in federal buildings and help lead market transformation through deployment of new technologies.

In 2011, the GPG program selected 16 technologies or practices for rigorous testing and evaluation. Evaluations are currently being performed in collaboration with the Department of Energy's National Laboratories, and a steady stream of results will be forthcoming throughout 2012."

The program is a good example of federal money and resources coming together to produce two things: 1) technology validation with M&V of in-field technology testing and 2) successful demonstration case studies. This program directly addresses major informational barriers in the field of advanced building technologies.

Part II. Advanced Building Technologies and Related Policies in China

Advanced building technologies

Building envelope

Cool roof

Cool roof technology in China has had a slow start. While there are no current national or sector standards, a draft of sector standards does exist. This is the result of a joint effort by the Building Materials Test and Certification Group Co., Ltd. and other enterprises and government representatives. Expected to be officially released in the near future, these sector standards should provide guidance for the further development of cool roof technology in China (Shengfeng Building Material Net 2012).

Energy-saving windows

Windows are crucial components for building energy efficiency – they are not only a source of energy gains and losses, but also affect lighting, ventilation, sound insulation and façade patterns. Energy-saving windows and doors need to meet certain standards in physical properties, including airtight capability, watertight capability, sound insulation, and thermal insulation.

Currently, domestic builders use PVC, aluminum, wood, GFRP insulation and aluminum alloy for windows and doors – materials that are for the most part not energy-saving, especially heat-conducting aluminum (Luo Shuxiang 2012). In order to minimize energy losses, conventional windows can be replaced by a number of advanced window types, including double-pane windows, heat-reflective coated glass, low-E glass, metal-containing glass that has undergone vacuum magnetron sputtering and radiologic processes, and smart windows such as having electro-chromic glass and photochromic glass. Additional tools include "super-efficient glazing" products, which offer a heat transfer coefficient of only 1W/(m2K) and 83 percent more energy efficient than ordinary glass, 64 percent more efficient than hollow glass, and 44 percent more than low-E hollow glass (China Glass Net 2012).

Full solid-state smart window (SW) is a newer technology that is gaining interests in the building, transportation, and electronics industries. Using electro-chromic materials, the SW can dynamically adjust solar output or input and visible spectrum, making it a popular material in automobile windscreens and large displays.

Shading system
Building shade is a form of building insulation that helps to reduce summer solar heat that enters the building interior through windows, roofs and walls. Building shading may refer to exterior windows, roofs, and walls, as well as roller blinds, movable louver shading, awning and shade veil. Developments in shading include new types of glass, such as heat-absorbing glass, heat reflective glass and low emission glass.

Building shading systems not only reduce solar radiation but also reduce power consumption compared to conventional air conditioning systems and lead to further energy savings. Proper shading can also adjust the incoming visible light to prevent glare.

HVAC system

Chilled beam system
Chilling beam systems originated in Europe and have been in use for over 20 years. Though in recent years they have been implemented in the United States, few applications of the technology exist in China.

The chilled beam system is composed of a fan-less dry coil and performs a convective heat transfer. Chilled beams can operate as passive chilled beams or active chilled beams. Active chilled beams, which intake an external air supply, can perform cooling and heating functions, whereas passive chilled beams can only perform cooling, making them unsuitable for heat pump systems. The coil bears only a sensible heat load but not a latent heat load in order to avoid condensation, which may trigger bacteria growth.

Chilled beams present sizable operational and environmental benefits over conventional A/C systems. Overall, chilled beams are low-maintenance: they can be installed quickly and require minimal repairs, as the device contains no moving parts like a conventional system's fan or filter. And as a fan-less system, chilled beams result in quieter rooms, while passive chilled beams barely produce any sound. Moreover, a smaller air duct means the chilled beams can operate in a smaller space than conventional systems. Chilled beams' use of high-temperature cold water for cooling also makes the device's operation energy efficient.

Chilled beams offer broad benefits – especially for users requiring high comfort – but the large initial investment still poses a major barrier to development. For the time being, construction costs in China are too high for chilled beams systems to be a popular alternative to conventional A/C systems, and the market's saturation with expensive foreign brands serves as a deterrent to popular use. In addition, installation depends on a tight building envelope as well as proper controls over water temperature and air humidity in order to prevent imbalances that induce the coil to produce condensate. As a result, chilled beams are not suitable in places with a relatively high latent heat load (Yang, Qian and Liu 2011).

Despite barriers to development, there are some successful cases of chilling beams, including the Beijing Environmental International Convention Compliance Tower and several foreign headquarters buildings (Li 2009).

Energy recovery ventilation device (ERV)

An energy recovery ventilation device achieves greater energy efficiency by recovering the energy of a room's exhausted air and using it to treat incoming fresh air. An ERV cools and dehumidifies fresh air in the summer and pre-warms and humidifies air in the winter. These devices are already implemented in many projects in China and most have achieved significant reductions in energy consumption. Implementation has been aided by the 2008 standard GB / T 21087-2007 "Air-to-Air Energy Recovery Device".

Air-to-air energy recovery devices may be named based on the type of energy recovered: sensible heat devices or total heat devices. ERV devices have various physical forms; including plate, runaround coil, liquid circulation (including surface type and direct contact type), heat pipe, and heat pump type. Devices not only recover different energies but also consume different energies (for example, heat recovery cartridge, the air-flow resistance of an added air filter or air duct, motor device, liquid circulating pump, and the heat pump all consume energy). As the engineering variables abound, the ERV device's efficacy within a HVAC system relies on careful consideration and scientific computation (Xu 2011).

The annual energy recovery of an ERV is dependent not only on the device itself but also on the air treatment mode of the HVAC system and energy recovery adjustments adopted in response to changes in outdoor weather conditions. If the device does not adopt proper adjustment methods when weather conditions change, an ERV device may actually increase the energy consumption of the air conditioning system.

Condensing boiler

A condensing boiler achieves high-efficiency by condensing the residual water vapor resultant from the boiler's flue gas emissions, thereby absorbing the latent water heat released by vapor condensation and the sensible heat from the boiler's emissions. Condensing boilers can be divided into three types based on its heat exchanger: contact type, recuperative- and contact-type, and contact- and recuperative-joint-type.

Compared with conventional water heaters, the condensing boiler achieves high thermal efficiency and produces low CO emissions, thus saving gas costs and minimizing its carbon footprint. Industry experts believe that condensing boilers will eventually replace the traditional stove and become a mainstream market product. The devices already enjoy wide popularity in Europe, where the market is saturated with condensers and many countries have already banned conventional household gas boilers. Some EU nations including the UK and Switzerland have also formulated related subsidy policies.

The Chinese market for condensing boilers, meanwhile, is in incipient stages, with growing market share in central and southern China. However, condensing boilers have failed to catch on in the north, primarily due to costs nearly 50 percent higher than conventional boilers. Moreover, government support remains lukewarm, and coupled with environmental factors – including less than ideal water quality, unstable water pressure, and differing quality of natural gas – adoption has been slow.

Yet despite a slow start, social and economic conditions are ripe for rapid development in China's condensing boiler market (Song 2012). Condensing technology will likely attract future investment due to a burgeoning national energy and emissions consciousness, aided by policies in the government "Twelfth Five-Year Plan" that call for significant reductions in carbon dioxide emissions. As of now, the Chinese government provides energy-efficiency subsidies for Grade I rated condensing heating boilers (Hangzhou Rejia HVAC Company n.d.).

Multi-evaporator air conditioners

Multi-evaporator air conditioning systems adapt to changes in the air conditioner's load by changing the flow rate of the refrigerant in the system and can achieve significant energy efficiency under part-load. The refrigerant in the indoor unit directly exchanges heat with the room's air to avoid a secondary heat transfer loss, unlike conventional air conditioning systems that transfer coolant to the air through water. Furthermore, the MEAC system design is simple, space-saving, and aesthetically complementary to interiors. MEAC systems also boast continuous declining equipment investment, and have subsequently found favor with HVAC designers.

Since their introduction in China in 1993, MEACs have enjoyed a relatively high market share, especially in eastern and southern China, regions with suitable climatic characteristics and developed economies. MEAC systems have since become one of hottest products on the central air-conditioner market in China (Qi 2011). At present, several Chinese national brands have made critical progress through technology R&D and product updates, boding well in a market inflated by high prices of imported brands. Development of MEAC systems has advanced from multi-line to fixed frequency to frequency conversion and then scroll, and from air cooling to water cooling to water source.

Chinese applications of MEAC systems are often in small and medium structures, offices buildings and public buildings. However, inefficiencies in applications and design do exist. For more efficient application of MEAC systems, attention must be paid to the applicable working conditions and the design principle of model systems (Zhu 2011). In addition, MEACs still require progress in technology, in design, and innovation of products, according to Wu Yuanwei, honorary chairman of Air-Conditioning Branch in the China Building HVAC Society.

Optimizing ventilation

Natural ventilation has clear advantages in energy efficiency and maintaining health and comfort, but simple natural ventilation suffers from many shortcomings, including lack of heat recovery capability, poor control and reliability, lack of stable air flow and temperature control, and vulnerability to outside environmental changes, such as a large change in wind pressure. New technologies and measures to improve natural ventilation systems (Zou and Wang 2007):

1) Multiple ventilations. Multiple ventilations allow switchover between the mechanical ventilation and the natural ventilation depending on the season or environment, which allows users to engage specific advantages of both natural and mechanical ventilation. The system’s switchover capability results in greater reductions in energy consumption and operating costs of the building air conditioning system.

2) Combine energy storage with night natural ventilation. The basic principle is to combine night ventilation with building structure cooling storage technology. The system utilizes thermal storage material to absorb large amounts of heat in the daytime to control potential rises in room temperature; at night, the system uses natural ventilation to adequately cool down the heat storage material in order to reduce indoor temperature fluctuations and regulate building temperature. Indoor air quality improves and energy consumption decreases.

3) Natural ventilation combined with double-deck curtain walls. Double-deck curtain walls with double (or triple) layers of glass act as the building envelope creating ventilation passages with certain widths and adjustable louvers between glass layers. These ventilation passages can ventilate outdoors as well as indoors, thereby reducing energy consumption and improving indoor air quality.

Natural ventilation seems a pragmatic technology for China to pursue, not only because of the strain China’s reliance on air conditioning places on its daily energy supplies but also because China’s five climatic zones cater well to natural ventilation. But China today lacks research and applications of the technology, and must carry out further theoretical and case studies (Mao and Song 2011). Special attention should be spent examining special urban climates and the many components of natural ventilation – including structure, materials, ventilation mode, ventilation control and operating lifetime of the building envelope.

Natural ventilation also makes sense to China as a survivability measure. With the risk that typhoons or earthquakes may wipe our grid power for days on end, a building that can be safe and relatively comfortable without power is a benefit.

Ground source heat pumps (GSHP)
After early engineering attempts during the late 20th century, ground source heat pump technology has now spread throughout China and large numbers of enterprises have become active in the design, manufacturing and construction of GSHPs. In a survey of nearly 4000 projects of 43 enterprises by Engineering Construction and Design magazine, all 31 provinces, municipalities and autonomous regions of China, save for Hong Kong Macao and Taiwan, have ground source heat pump projects (Wu 2011).

The Chinese state gives substantial support to GSHP technology. In 2005, the Ministry of Housing and Urban-Rural Development listed GSHP as one of the new technologies to be promoted; later that year the ministry put forward a national standard outlined in “Engineering and Technical Specifications for Ground Source Heat Pump Systems” and initiated a special fund to subsidize a national demonstration project. In 2010, China ranked second after the United States in GSHP applications with an annual growth rate of 30 percent, installations in over 31 provinces and square footage covering 140 million square meters. 80 percent of GSHP projects are concentrated in the northeast, south and north in cities including Beijing, Tianjin, Henan, Jiangsu, Liaoning, and Shandong. Continued development has slashed construction costs from the initial RMB 400-450 cost per building area to RMB 220-320 per building area.

However, there is a case of a failed GSHP project due to blind engineering practices, which in turn was inexplicably attributed to failures in GSHP technology itself. In truth, unsuccessful trials were affected by lack of planning, guidance, and suitable evaluation, as well as poor operational management and insufficient follow-up supervision. Other hurdles to GSHP technology include the public perception that energy-saving technology does not save money.

In the end, China is a vast country with large potential for developing ground source heat pumps to help mitigate its irrational energy structure and reduce energy consumption. Chinese applications of GSHPs are in its beginning stages, and the current development seems a tad hasty. Moving forward, proper site selection for ground source heat pump installation can improve the utilization rate of the geothermal source and maximize energy-saving efforts in China (Lu Peng 2012) (Pan, Wang and Cai 2012).

Domestic hot water system

Heat pump water heater

A heat pump water heater (HPWH) is an energy-saving product to supply sanitary hot water. Using an electric heat pump, the HPWH uses refrigerant to absorb low-grade heat in the air while a heat exchanger transfers the low-grade heat energy to the water, subsequently producing and sending hot water to users via a water circulation system. Heat pump water heaters can be identified by their energy sources – air, ground or water – and by their application sites – domestic or commercial.

Use of ground source and water source heat pumps has some limitations while air source heat pumps prove more versatile. Water source heat pump systems are limited by the water system and affected by local policies on water resource utilization. Meanwhile, ground source heat pumps pose relatively high engineering costs, as they require sufficient space to bury their associated heat exchanger as well as an efficient method of recharging. For these reasons, air-source heat pumps – which take air as a low-temperature heat source – are commonly used over ground and water source systems in China, for its lessened source limitations and flexible installation and application.

Commercial heat pump water heaters have been long in use; they are essentially derivations of cold and hot water central air conditioning systems, except larger-scale and with more mature technology. Domestic household HPWHs officially entered the market during 2002, and, coupled with vigorous promotion of familiar domestic brands and national standards in 2008, heat pump water heaters have maintained rapid development.

Still, there are several problems with this technology compared to conventional systems. First, current designs for heat pump water heaters are large and may add inconvenience to installation, thus limiting its appeal. Second, as a new product, the heat pump water heater remains only somewhat understood by consumers.

Improvements to the heat pump water heater are still expected as the product matures, hopefully resolving larger concerns of its environmental adaptability, users' cognition, and large design as well as smaller issues such as defrosting in winter and high costs. But the HPWH maintains unique advantages in energy savings, safety and environmental protection that are unmatched by other traditional water heaters. It is likely that the heat pump water heater will become a mainstream product in the future water heater market, especially in hotel applications (Peng 2008) (Sun 2011).

Device for recovering residual heat from condensation

Residual heat recovery from steam condensation has very high economic benefits and is known as one of the most effective energy-saving methods. At a recycling rate of one ton of condensate per hour, steam condensation is equivalent to saving 30 tons of standard coal annually. Condensate recovery systems recover high temperature condensate exhausted by steam systems, maximizing the use of condensate heat and saving water and fuel.

Condensate recovery systems can be divided into open and closed recovery systems. The closed recovery system is often preferred for higher efficiency and less environmental pollution. Steam condensate recovery technology's benefits include a short investment cycle, quick results and clear energy savings, offering high appeal to the majority of steam users (Zhang 2011).

Despite substantial economic benefits, the technology has not been widely applied across industries, mainly due to problems in water quality as well as design, operation and economic factors. However, current technology has huge potential and development is set to accelerate – already, the scientific and technological progress and sustainable development of the industry, including improvements in condensate recycling techniques and cost reductions, are encouraging (Huang 2009) (Wang and Chai 2011).

Solar hot water system
A solar water heater produces hot water by converting solar energy into heat and subsequently heating water from a low temperature to a high temperature. Based on the device's structure, a solar water heater can be named a vacuum tube heater or flat plate heater. The vacuum tube solar water heater is currently a market leader with 80 percent domestic market share. The solar water heater consists of a heat collector (either vacuum tube or flat plate), heat insulation water tank, bracket, connecting tubes and control components. In northern China, solar water heaters are generally used for more than six months while in the south they can be used for more than 10 months (Z. Wang 2012).

Statistics shows that China claims the titles of largest producer and largest consumer of solar water heaters. The solar energy industry has been developing rapidly at an annual growth rate of 20-30 percent in recent years, and its market share in China's water heater market largely overshadows that of electric and gas water heaters. Statistics show that output of solar water heaters in 2010 was about 49 million square meters, valued over RMB 73.5 billion. By the end of 2010, China's solar water heater stocks were 168 million square meters, and by the end of "12th Five-Year Plan" in 2015 stocks are projected to number 400 million square meters – an unprecedented expansion of market capacity. With continuing promotion and popularization of new energy coupled with growing demand for a high quality of life, the Chinese solar water heater market is set for rapid development.

The government has passed numerous measures to promote market conditions for energy-saving appliances. In 2009, solar water heaters were included in the subsidy policy "Home appliances to the countryside," which stipulates subsidies for farmers who buy home appliances in rural areas. In 2012, the government declared the "Beneficial Project for Energy-Saving Products," which will give subsidies for the promotion, supervision and inspection, standard identification, information management, and training for energy-efficient products, including air conditioners, lighting products, home water heaters, refrigerators, and washing machines. Later in June 2012, the government passed the "Rules for the Implementation of Promotion of Efficient Solar Water Heaters Relating to the Beneficial Project of Energy-Saving Products". In 2012, the solar water heater industry suffered from an overcapacity in the solar photovoltaic industry, resulting in overall sluggish performance. But with constant demand increases, industry acceleration and favorable government policies, the solar water heater industry is set to usher in a major development phase (Investigation and Analysis of the Market Status of Solar Water Heaters n.d.).

Appliances and electronic equipment

Energy-saving sockets

Energy-saving sockets aim to reduce power consumption during both standby mode and start time. In a master/slave setup, the socket controls the operation of the slave devices by means of coil induction according to a current change in the master machine, and through processing of integrated circuits and ON/OFF of the relays. For example, turning off the host computer will automatically turn off the printer, scanner, stereo and other connected devices. The appliance itself determines power consumption at startup, but energy-saving sockets can help carry out the ON/OFF operation to save energy. Solving the "standby power consumption" problem is quite significant for energy-saving goals, as standby power consumption by TV sets and other audio-visual products account for 68.6 percent of overall standby power consumption. An energy-saving socket can eliminate standby power consumption, prevent lightning strikes, resist fire, and provide overload protection.

The energy-saving socket has been around for some time, but only recently has it been developed extensively. Currently, there are sockets specified for computers, TV sets, water dispensers and other energy-saving appliances. Though a useful tool, the socket's price remains relatively high. (Cha 2011) (Xing, Zhou and Liu 2011).

Smart appliances

Smart appliances generally have the following characteristics: parameter acquisition and digitized processing, self-monitoring and diagnostic capability, self-adaptive control capacity and information exchange capability.

Smart appliances themselves have small effects on energy-saving but can be used in energy-saving systems. For example, electricity-saving systems can calculate and analyze the optimal power-saving strategy to be selected by users based on different power prices at different times, thus influencing demand side response. Currently, smart appliances are in research stages with several applications (Jiang 2010) (Liang, Li and Shi 2012).

Lighting

Lighting energy-saving methods mainly include: selection of quality electric light sources, selection of energy-saving lighting accessories, installation of power savers, scientific design of energy-efficient lighting and enhanced maintenance and management (Gong 2011).

Efforts have been made at the national and local level to promote energy-saving lighting. Examples include the Ministry of Finance and National Development and Reform Commission's financial subsidy policy to promote 150 million compact fluorescent lamps (CFLs) during the "Eleventh Five-Year Plan" period; the central government's 30 percent subsidy on manufacturer prices through bidding; and the 50 percent subsidy on manufacturer prices, through bidding, for every efficient lighting product purchased by urban and rural consumers.

At present, the Chinese LED lighting market is doing fairly well. LED lights offers operational benefits – small size, high brightness, low heat – as well as energy-saving benefits including low power consumption, long lifetime, and durability. In 2009, the National Development and Reform Commission and another five ministries jointly presented the "Opinion on Development of Semiconductor Lighting Energy-Efficient Industry" and proposed that "by the year of 2015, the average annual growth rate of the output value of the semiconductor lighting energy-efficient industry will be about 30 percent, the market share shall gradually increase, functional lighting will reach about 20 percent, LCD backlight will be over 50 percent, and market share of the landscape decoration products shall be more than 70 percent." In the same year, the Ministry of Science and Technology launched a demonstration program named "Ten Cities, Ten Thousand Lamps," for 21 of the mainland's developed cities including Beijing, Shanghai, Shenzhen, and Wuhan with the goal of promoting the development of the LED industry and reducing energy consumption. In May 2011, 16 cities including Beijing, Changzhou, Hefei, Qingdao, Guangzhou, Haikou and Baoji were confirmed as the second installment of "Ten Cities, Ten Thousand Lamps" demonstration. The program provided a huge market for the Chinese LED industry as well as a boost for the development of the international LED industry. Local governments at all levels have shown great enthusiasm for LED lighting and have invested heavily in land and implemented significant preferential policies on taxation, technology development, innovation, and equipment purchases. Downsides of the recent industry development include lower access to the market, emerging enterprises without experience or technical support, and a corporate focus on profits rather than on products, resulting in great variation in LED product quality.

In 2010, China's LED lighting market totaled RMB 16 billion, a year-on-year increase of 40 percent. Applications of LED lighting most often go toward LED landscape lighting, street lighting, special lighting and automotive lighting, which account for 89.6 percent of the overall market sales. In 2012, the LED commercial lighting market in China is far from satisfactory, as high prices presented the biggest obstacle for market promotion. In 2013, LED enterprises and traditional lighting enterprises are competing fiercely in the commercial lighting and residential lighting markets (htt3).

Building control

Energy management control system

The Chinese government has shown piqued interest in enhancing energy efficiency monitoring and promoting energy efficiency. Since 2007, authorities have launched a series of energy-saving laws, regulations and subsidies. In June 2007, the State Council put forward "Comprehensive Work Program for Energy-saving and Emission Reduction" that called for the establishment and continued development of an energy-saving index system as well as a monitoring and evaluation system, strict management of building energy efficiency, with overall emphasis on management best practices for national buildings and large public buildings; additional measures called for implementation of a school campus energy monitoring program (Xinhua net n.d.).

However, there are still some obstacles to further promotion of building energy management systems. For one, the systems need better technical support and an improved industrialized process. Currently, engineering of the building energy management system remains at a cursory "energy consumption monitoring" level, making it difficult to intervene with existing building control systems, there is no multi-user distribution processing ability, analytical ability is not sufficient, and "management" has not been characterized (P. Lin 2012).

Smart electricity meter

A smart electricity meter is an intelligent terminal of the "Smart Grid," equipped with many intelligent functions above and beyond a traditional meter. In order to interface with the new smart grid and new energies, a smart meter's intelligent capabilities include two-way multiple rates metering, client terminal control, various data transfer modes and bi-directional data communication, and anti-theft.

Smart meters have become a central focus in China's construction of a national smart grid. Currently, China has entered the complete construction phase of the smart grid, resulting in a huge market demand for smart meter production. According to reports, a series of new technical standards will come into effect in August 2013; the hope is standardization will improve quality management and control functions of the smart meters and provide a strong impetus for improved development. By the end of 2012, the State Grid Corporation of China had accumulated bids for 184 million smart meters. According to smart grid plans of the State Grid Corporation, China is projected to install 230 million smart meters in 2015 (Li, Chen and Qin 2011) (Yu n.d.).

Demand response (DR)
Among the United States' electricity market reforms, demand response targeting stands a central concept due to its role in maintaining system reliability and improving market efficiency. According to the U.S. Department of Energy, DR in the power market can be categorized as price-based DR or incentive-based DR. These two approaches are based on market conditions which are, at present, not mature in China. With minimal market-based DR applications in China, there is mainly passive load reduction for safety purpose, for major users, most of them implement the orderly use of electricity mainly by administrative means, i.e., in exceptional circumstances, it requires the partial users to shift the peak loads, and the small and medium users are basically to only have one kind of response mode -- passive load reduction (Zhang, Wang and Wang 2008).

Based upon DR implementation cases in various countries, DR has proven to be an effective method to mitigate short-term system capacity shortages and to delay investment in grid upgrades. Especially in a competitive power market, DR can reduce electricity prices as well as fluctuations in prices, optimize resource allocation and ensure stable operation of the market, making it an important strategic tool in the electricity industry, economic development and environmental protection.

China, in beginning stages of power market reforms, should take note of experiences and lessons from foreign power market development, especially on structural market design. Implementation of China's demand-side management began in 1992, focusing mainly on promotion of energy-saving products and pilot programs for peak load shifting. In 2005, with sponsorship and assistance from NRDC, Jiangsu province began a large energy efficiency program with California, the first of its kind in China. Focused on energy efficiency incentive mechanisms, the project lasted five years and has since resulted in the adoption of a Demand-Side Management (DSM) strategy, along with the "Power DSM Approach" and "Guiding Opinion for Strengthening DSM". China mainly uses a time-of-day tariff and peak tariff for managing demand; in addition, some provinces and cities give subsidies to enterprises that voluntarily cut their load during peak periods. While many Chinese cities have benefitted economically with peak-valley pricing, pricing in some cities is not always reasonable.

Current Chinese demand for electricity makes the implementation of DR particularly necessary and urgent. It will take policy measures rather than market pricing tools to implement DSM first, which will then hopefully lead to future market pricing tools to help influence demand time and level (Wang, Huang and Chen 2007) (State Electric Science Research Institute 2011).

Distributed energy resources

Distributed energy resources (DER) systems provide various unique advantages, including energy conservation, emission reduction, cost saving, security, peak load shifting, and contribute to a recycling economy. Distributed Energy Resources equipment have undergone continued improvement in performance, steady reductions in cost, and extension of its applications to various sites including office buildings, hotels, shops, restaurants, residential buildings, schools, hospitals, charity houses, nursing homes, universities, and sporting stadiums.

At present, DER utilization makes up a relatively small proportion of total usage in China, as DER applications have only just begun, led by domestic R&D institutions, universities, and power supply departments performing research, projects and products (such as the Chinese Academy of Sciences' numerous small-scale solar photovoltaic power systems generating 420KW). In addition, there is a group of combined cooling, heating, and power (CCHP) demonstration projects underway in residential areas, shopping malls, and university towns in Beijing, Shanghai, and Guangzhou. DER systems using natural gas as fuel have entered a substantive development and implementation phase. In 2011, total installed capacity of distributed natural gas generation was about 5 million KW, less than 1 percent of gross installed capacity nationwide. In April of 2010, the Bureau of Energy proposed to construct 1000 natural gas DER projects by 2011, and popularize distributed energy resources system in large cities until 2020 with installed capacity up to 50 million KW, over 10 times capacity in 2010. (Cong 2013).

In order to promote development of distributed energy resources, the Chinese government and relevant departments have implemented special provisions for combined heat and power (CHP), such as Energy Conservation Law of the People's Republic of China, Provision on Developing CHP, 11th Five-Year Planning for Energy Development, 2010 CHP Development Planning and 2020 Long-term Development Target, and Comments on Doing a Good Job of Distributed Generation Grid Service Work. All districts and departments also introduced corresponding subsidy policies for equipment and feed-in tariff.

In the next several years, distributed generation is likely to become an important supplement for centralized generation and also an important player in the comprehensive utilization of energy. The potential market is huge, as China's urban and rural areas continue searching for power utilization solutions. Once it manages to break major obstacles, including price and grid mechanisms, we project distributed energy resources systems will undergo rapid development. In short, the application prospects of distributed energy resources technology are quite promising (Chinagas.org 2012).

Solar photovoltaic generation

Photovoltaic generation directly converts light energy into electric energy by capturing the sun's energy via the photovoltaic method for independent use or for grid power. A photovoltaic generation system is composed of three main parts: solar cell panels, controller, and inverter. Photovoltaic generation equipment is very developed, reliable, and stable with long service life, convenient installation and minimal maintenance.

Development and utilization potential of solar energy resources is high in China, a country where annual reserves of coal now stand at 1700 billion tons. The solar photovoltaic generation industry has undergone robust development since 2006. In 2011, for which the most recent numbers are available, photovoltaic generation installations in China rose by 5 times compared to 2010 and battery production was up to 20GW, counting for 65 percent of worldwide production. By the end of 2010, China's installed capacity of photovoltaic generation was up to 600,000 KW, a newly-increased photovoltaic grid capacity was 211,600KW, and collective grid capacity was 240,000KW. Since 2010, various problems have slowed industry development, largely resultant of domestic enterprises' focus on production expansion and market share while neglecting technological development and innovation (Li, Chen and He 2011) (Z. Xu 2012).

In order to encourage the domestic photovoltaic market, numerous government departments have introduced policies to support industrial development, including the 12th Five-Year Planning for Solar Power Generation Development which sharply increased development targets for solar power generation in 2015 from 10GW to 21GW. Other projects include "Golden Sun Demonstration Project" and a State Grid Corporation release of Comments on Promoting Grid Management of Distributed Photovoltaic Power Generation in 2012 to encourage advances in solar energy demonstration projects and the power grid, which for the first time proposed to determine a PV power station benchmark price of the regional grid according to resource conditions, an inaugural altering of industry structure that gives domestic demand a priority equivalent to the priority previously given to overseas markets. Still in incipient stages of policy change, distributed photovoltaic power generation in China still faces various difficulties in implementing large-scale applications of State policies, management systems, technological standards, and business models.

Integrated Building Design

Integrated Building Design is a new concept that comprehensively incorporates with all building elements – including external environment, building structure and technological equipment – and elegantly fuses building and new technology together. During its initial stage in the 1990s, integrated design in China was only a superficially understood concept, but engineering design has since then made some gains. For example, projects by Hangzhou ICBC Financial Comprehensive Building and Hangzhou Bank of Communications Financial Building employed architects in order to achieve an optimal integrated design; their architects served as innovators and collaborators in design as well as the overall construction process.

Integrated building design can enhance a building's adaptability, which proves a necessary capability in regards to energy conservation and environmental protection. With the constant development of the economy and scientific technology in China, building design will inevitably become more advanced in technology and scientifically. In the near future, we expect increasingly improved integrated building design during China's construction phase (Shi 2011) (Ren 2012).

Barriers to advanced building technologies

The overwhelming global motivation for promoting building energy conservation is to mitigate the impacts of climate change. China's energy production relies heavily on coal and other fossil fuels, linking the country's energy consumption closely to carbon dioxide emissions and its adverse environmental effects. Using efficient and advanced building energy conservation products has clear environmental benefits as well as energy savings, but it also may be advertised to residents as a means to increase comfort level and quality of living. As demand for smart energy usage rises accordingly, security of China's energy supply will strengthen and expenses previously spent on energy can be applied to welfare projects, job creation, and economic stimulus.

Many factors influence business decisions on electing to use energy-saving technologies. Among these various factors, energy cost savings, energy security, and existing energy conservation policies rank highest, according to a report by Johnson Controls (Johnson control Energy Saving Research Institute 2012),. Policy, according to the report, is the most important factor for the Chinese, though the factor ranks just 8th among global market players. Other influencing factors include potential boosts to brand or public image, government/public utility incentives or associated interest, reductions in greenhouse gas emissions, investor pressure, and increases to asset value. In comparison, the report finds that U.S. businesses are mainly influenced by energy cost savings, government/public utility incentives or associated interest, and boosts to brand or public image.

The research further reports that there are five key factors influencing decisions regarding building energy-saving technology popularization and application: absence of energy-saving awareness, lack of energy-saving technology, uncertainty of cost savings, inability to meet investors' requirements for payback period, and shortage of funds. It is widely believed the biggest barrier to popularizing building energy-saving in China is a shortage of professional skills, followed by uncertainty of cost savings, inadequate return on investment, shortage of funds, differing owner and tenant motivations, unorganized owners, and lack of energy-saving awareness. As for the United States, shortage of funds is the primary factor obstructing development of building energy-saving, followed by investors' requirement of short investment payback period, market failure to capitalize energy savings, uncertainty of cost savings, little energy-saving awareness, and lack of technology (Johnson control Energy Saving Research Institute 2012). Besides, the legal environment and mandatory force of energy-saving policies is also one of key factors influencing launch of the work. Barriers for advanced building technologies can be concluded into the following three types after comprehensive analysis: informational, awareness, and intellectual barriers, economic barriers, and regulatory barriers. Specific explanations are as follows:

Informational, awareness and knowledge barriers

The following three sections on informational, economic, and management barriers have drawn information from the following references: (Johnson control Energy Saving Research Institute 2012); (HVAC 2012); (Building Energy Saving 2012); (C. Wang 2012); (S&T Development Promotion Center of Ministry of Construction n.d.); (L. Lin 2005); (W. Liang n.d.); (Sun and Song 2011); (L. Song 2009); (Han 2010); (Cao 2012); (Z. Zhang 2012); (He 2011); (Policy Research Center of MoHURD 2012); (Cheng 2009); (China Securities Journal 2013); (Ananymous 2013); (Jinan Daily 2012); (Qingdao Daily 2012)

Fragmented design and decision-making process
The decision-making process is complex and fragmented by numerous players – including investors, owners, occupants, developers, design and consulting institutions – whose interests may not align.

Incomplete and imperfect information needed for decision-making
Information about energy-efficient building technology is often incomplete, unavailable, expensive, and difficult to obtain. The complexity of building design, construction, and operation makes it difficult to wholly convey the degree of a building's energy efficiency.

Unfamiliarity with new energy-saving technology
Architects and engineers will often decline to use new technologies they are unfamiliar with to avoid risks to their project and clients. Even if they do wish to use advanced building technologies, there are few means to become familiar with them, as new technologies often lack sufficient performance data or safety data outside of the laboratory. Moreover, architects lack the tools to simulate and evaluate technology performance and its integration with other energy-saving technologies.

Unregulated energy-saving design model and still remains at the same relative energy-saving level

Model indicators with values of 50 percent and 65 percent leave deep impressions in people's minds, but the actual building energy consumption represented by these numbers is not clear, which has obstructed effective promotion of total energy consumption forced mechanism. Complicating things further, the software model for energy-saving design is largely unregulated and produces sizeable discrepancies in results. However, this could be fixed. For example, California already regulates software for building compliance for several decades.

Different quality and cost products

Energy-saving products suffer cut-throat competition from non-energy-saving products that benefit from low consumer awareness and a lack of market direction and supervision. Products that meet energy-saving standards are priced high and occupy little market share. The number of enterprises producing energy-saving products is high, but they operate mostly at a low scale, and it has proven difficult to widen the difference. Comparatively speaking, conventional products at lower prices are more attractive and have indeed made greater market impact.

General public lacks both energy-saving awareness and knowledge

The public lacks knowledge on building energy consumption, which has led the public to underestimate the role buildings play in contributing to and potentially mitigating climate change. The public largely lacks the knowledge and technology to evaluate energy-saving buildings and subsequently become unwilling to purchase energy-saving products or resist energy-saving retrofitting.

Evaluation criterion is only on the basis of adopting energy-saving technology instead of economic efficiency

Green building standards are still evaluated based on formal numbers on adoption of energy-saving technology products, instead of considering investment, operating economy, or actual energy-savings. China's standards should fully consider energy-saving technology and their economy.

Economic barriers

High initial investment or projected investment

Building owners and investors are often reluctant to pay for products that produce cost savings over a whole life cycle. Building designs with low energy consumption generally cost more to design and build due to integrated energy-savings design, requiring systems integration and systems controls. Investment in energy efficiency also competes directly with funds that can be invested in other business functions at the time of decision-making. In truth, the proportion of incremental costs for newly constructed energy-saving buildings is not high in comparison to costs to retrofit existing buildings.

However, residents, real estate agents, architects, and engineers misjudge building energy-saving costs and benefits and grow reluctant to invest.

Lack of financing or access to loans
Many businesses may have trouble finding financing support for energy efficiency upgrades, and most financial institutions are not willing to invest in small-scale projects due to relatively high transaction costs, slow installment payments and questionable security of the investment.

Lack of cost-recovery mechanisms
There is a lack of cost-recovery mechanisms in China for energy efficiency investments hinder electric utilities from promoting such technologies.

Split incentives
Building developers and owners often do not invest in energy efficiency in new construction or retrofitting existing buildings, considering it a loss taken on behalf of residents and lessees who benefit from lower energy bills. That is, until it is impossible for them to co-share the energy-saving profits.

Distorted energy pricing structure
Coal power remains priced attractively low while natural gas remains relatively high, though natural gas distributed CHP projects have high efficiency. The price mechanism has made users unwilling to invest in lower-emissions projects, and they continue to purchase grids at a low price without operating the purchased equipment.

Lack of energy-saving incentives
Most property management companies have no energy-saving motivations, as added costs for building energy-saving burden construction businesses while benefits flow to end users. Without incentive policies in place, users of energy-saving products and technology tend to lack energy-saving awareness or motivations. To remedy this, corresponding incentives should be offered to businesses in charge of design and construction, manufacturers, and intermediary service agencies. It is advised to select the most strongly incentivized players and most effective incentive targets to implement economic and policy incentives, otherwise people will begin to believe that "conservation does nothing."

Management barriers

Code lock-in or prescriptive codes: Certain regulations set up by some energy efficiency codes and prescriptive codes occasionally can obstruct the application of other technologies. Interconnection and high charges for distributed energy resources: Utilities have historically been unfriendly to the development of distributed generation, imposing complex procedures and often costly fees for interconnection. But with the recent issuance of Comments on Doing a Good Job of Distributed Generation Grid-in Service, the grid-in process in China may be simplified and optimized.

Lack of satisfactory compensation for feed-in tariff of distributed energy resources
Although funds have been collected from special funds for renewable energy resources to support distributed generation grid-in, the compensation effort is still not strong enough.

Low property management level
Property management companies act as operating controller of energy-using equipment, so their attitude to energy saving directly determines implementation. Researchers show that if there is a requirement for energy-saving performance in property management, property companies will positively implement energy-saving management; on the other hand, if property companies have the right to regulate and control energy-using equipment without responsibility over energy costs, they predictably harbor little concern for energy savings. Thus, the management of property companies holds a large influence on energy-saving efforts of existing building.

Imperfect legal system and energy efficiency labeling
The provision in Electric Power Law that permits the establishment of only one power business institution within one power generation area restricts other power enterprises and hinders the development of distributed generation. Experience home and abroad has proven that specifying a building efficiency label system through legislation is beneficial for fully stressing the function of the market to energy players including construction companies and evaluation agencies. It is advised that building efficiency labeling should distinguish between different conditions, such as mandatory or voluntary.

Australia has found that the presence of labels is correlated to taking energy management actions, including both retrofits and improved awareness, operational improvements and training on how to operate buildings efficiently

In summary, the lack of professional technical knowledge has been the biggest barrier for China’s quest to advance energy-saving technology, followed by uncertainty in quantifying energy savings. In addition, the payback time for energy efficiency investments is usually too long to attract private investors. To address these problems, China should continue its great efforts in supporting demonstration projects and providing financial incentives pioneers. Making building energy codes and equipment standards stricter over time will also be important.

Overview of China's Energy Efficiency Policies for the Building Sector

In order to promote building energy efficiency, the Ministry of Construction (changed to Ministry of Housing and Urban-Rural Development in 2008) issued the *Regulation on Energy Saving in Civil Buildings* in 1999 and revised it in 2005. Such regulation laid a solid foundation for the building energy efficiency legislation.

Since 2004, high importance has been attached to building energy efficiency. Energy conservation has become a basic national policy of China. The national energy development strategy is required to give top considerations on energy conservation while planning energy development. *The Law of the People's Republic of China on Energy Conservation* amended and adopted at the 30th Meeting of the Standing Committee of the Tenth National People's Congress of the People's Republic of China was promulgated on October 28, 2007. In 2008, the *Regulations on Energy Conservation in Civil Buildings* and *Energy Conservation Regulations for State-funded Institutions* were issued. These laws and regulations strictly set the requirements for building energy efficiency and greatly speeded up the booming of energy efficiency in the building sector alongside industrial and transportation sectors. Subsequently, similar local laws have been issued. (Tu 2010)

Energy-saving incentives

Currently, government's incentive policies and programs for building energy efficiency are mainly focused on financial support, tax credit, preferential loans and subsidies, specifically focused on green building, utilization of renewable energy and energy-saving retrofit of existing buildings:

<u>Retrofitting existing buildings for energy saving:</u> In order to complete the task for retrofit of the existing buildings of 150 million m2 in the northern heating region during the 11th Five-Year plan period, in 2007 the Ministry of Finance (MOF) and the Ministry of Housing and Urban-Rural Development (MoHURD) promulgated *Interim Methods for Managing Incentive Funds for Retrofitting the Existing Residential Buildings for Heat Metering and Energy-Saving in the Northern Heating Region* (FD [2007] No. 957).

With the encouragement of this policy, energy-saving work in the northern region is carried out gradually; it fulfilled the energy-saving retrofit task in the 11th Five-Year Plan period with a retrofitted area of 182 million square meters.

In the 12th Five-Year Plan period, in order to expand the retrofit scale of the existing buildings, MOF and MoHURD jointly promulgated a *Notice on Enhancing Retrofit of Heat Metering for Energy Saving in Existing Residential Buildings in the Northern Heating Region* (FD [2011] No. 12).

Meanwhile, in order to extend the retrofit coverage from the northern region to the "hot summer, cold winter" regions, MOF and MoHURD jointly issued another document entitled *Implementation Guidelines on Promoting Energy-saving Retrofit of the Existing Residential Buildings in Regions Hot in Summer and Cold in Winter* (BS [2012] No.55). Accompanied with it was a *Notice on Interim Methods for Managing Subsidy Funds of Energy-Saving Retrofit of the Existing Residential Buildings in Regions Hot in Summer and Cold in Winter* (FD [2012] No. 148).

<u>Renewable energy utilized in buildings:</u> From 2006 to 2008, MoHURD and MOF jointly published a series of incentive policies to encourage renewable energy demonstration application in the buildings, including *Implementation Guidelines on Promoting Renewable Energy Application in Buildings* (BS [2006] No. 213), *Notice on Releasing the Evaluation Methods of Demonstration Project for Application of Renewable Energy in Buildings* (FD [2006] No. 459), *Notice on Releasing the Interim Methods of Special Funds Management of Renewable Energy Application in Buildings* (Caijian [2006] No. 460), *Notice on Strengthening Application Demonstration Management of Renewable Energy in Building* (Caijian [2007] No. 38), *Notice on Investigating, Reviewing and Organizing to Apply for Application Demonstration Project of Renewable Energy in Building* (Caibanjian [2007] No. 75), and *Notice on Inviting 2008 Applications for Demonstration Projects on Renewable Energy Use in Buildings* (Caijian [2008] No. 64). These incentive grants helped the government to explore effective ways of scaling up renewable energy use in buildings nationwide.

Through three years of supporting demonstration projects to accumulate experience in technology appropriateness, management, and operations, the government started to expand the effort in 2009 by moving away from supporting individual projects toward supporting regional initiatives. In 2009, MOF and MoHURD jointly released the *Implementation Program to Accelerate Application of Renewable Energy in Rural Areas* (FD [2009] No. 306) and the *Implementation Program on Application for City Demonstration of Renewable Energy in Buildings* (FD [2009] No. 305). Later on, the following policies were also rolled out: *Notice on Inviting 2010 Applications for Urban and Rural Demonstration Projects on Renewable Energy Use in Buildings* (FDO [2010] No. 34), *Notice on Inviting 2011 Applications for Renewable Energy Utilization in Buildings* (FDO [2011] No. 38), and *Notice on Organizing 2012 Demonstration Projects on Renewable Energy Utilization in Buildings* (FDO [2011] No. 167).

Current financial incentives are mainly in the following six areas: province-level key concentrated areas for promoting renewable energy applications in buildings, newly added demonstration cities and counties for renewable energy applications in buildings, approved new areas of demonstration counties for promoting renewable energy applications in buildings, concentrated contiguous demonstration areas (towns) for promoting renewable energy applications in buildings, collected significant application and demonstration projects for promoting it, and the projects on R & D and industrialization projects of renewable energy applications the buildings.

Building Integrated PV: Regarding building integrated photovoltaic applications, MOF and MoHURD jointly issued *Implementation Guidelines on Accelerating Solar PV Applications in Buildings* (FD [2009] No. 128) and *Notice of Releasing Application Guidelines for Demonstration Projects on Solar PV Applications in Buildings* (FDO [2009] No. 34) in 2009.

In 2009, the energy efficiency subsidies for building materials and community-scale BIPV projects were RMB 20/W or below; and for roof and wall mounted BIPV projects were RMB 15/W or below. The actual subsidy level of a project was determined based on the project's incremental costs and the combination of energy efficiency measures used. In subsequent years, these subsidies were adjusted based on the sector's development.

In 2010, MOF and MoHURD put out a *Notice on Inviting 2010 Applications for Demonstration Projects on Solar PV in Buildings* (FDO [2010] No. 29). The subsidy levels in that year were RMB 17/W for building materials and community scale BIPV projects, and RMB 13/W for roof and wall mounted BIPV projects. In 2011, engineering and installation of PV on buildings was subsidized at RMB 6/W to project owners.

To support wider application of PV in buildings, MOF and MoHURD issued a *Notice on Organizing 2012 Demonstration Projects on Solar PV Applications in Buildings* (Caibanjian [2011] No. 187), and a *Notice on Inviting Applications for "Golden Sun" Demonstration Projects Concerning PV Applications in Buildings* (Caibanjian [2012] No. 148). This incentive program supports PV applications in demonstration areas and the demonstration of Building Integrated PV (BIPV). The interim subsidy level was at RMB 9 per watt of installed capacity for those projects that use PV panels as building material closely integrated with building height; for other common ways of installing PV panels on buildings, the interim subsidy was at RMB 7.5 per watt.

The economic incentives mentioned above played positive roles in promoting the application of photovoltaic technology in buildings in China.

Large non-residential building and energy efficiency retrofit: In 2007, MOF and MoHURD jointly issued an *Interim Method for Management of Special Funds on Energy Conservation for National Government Office Buildings and Large Public Buildings* (FD [2007] No. 558). This interim method mainly offered subsidies for energy monitoring systems and energy retrofits.

The MOF and MoHURD jointly issued a *Notice on Inviting Applications for Grants to Support Construction of Energy Monitoring Systems in National Government Office Buildings and Large*

Public Buildings (FDO [2010] No. 28) in 2010 and a *Notice on Further Promoting Public Building Energy Conservation* (FD [2011] No. 207) in 2011. These Notices required that the selected cities for retrofit demonstration complete at least 4 million square meters of energy retrofit in within two years. The central government would provide grant funds to these cities -- in principle at RMB 20/m^2 but also taking into account the quantity and retrofit contents.

In 2012, MOF and MoHURD issued a *Notice on Organizing 2012 Energy Efficiency Demonstration Projects for Commercial and Public Buildings* (FOD [2012] No. 28). The financial incentives covered the development and installation of dynamic monitoring platforms for commercial buildings and universities and pilot cities' energy retrofits in commercial buildings and universities.

<u>Green buildings:</u> In 2004, MoHURD set up a National Green Building Innovation Reward, which is divided into engineering project category and technology and product category. The engineering project reward includes comprehensive green building reward, special reward for intelligent building innovation, and special reward for innovation on energy conservation. The technology and product reward supports the new technologies, new products, and new processes applied in green building projects. MOF and MoHURD jointly issued a document entitled *Implementation Guidelines on Speeding Up the Promotion of Development of Green Buildings in China* (FB [2012] No.167), which regulates the reward levels. For a single building, the reward is RMB 45/m^2 for 2-star green building certification, RMB 80/m^2 for 3-star certification. The reward levels will be adjusted based on technological progress and cost changes. At "eco-city" scale, the maximum reward was RMB 50 million and the actual level of reward depends on multiple factors, such as the size of planning area, the scale of green buildings, certification rates obtained, and the function of the green buildings.

Local governments have also adopted supplementary subsidies for green buildings, e.g., *Special Supportive Procedures for Energy Efficient Building Projects in Shanghai* by the Shanghai government. This policy specifies to subsidize high-standard projects, such as green buildings with energy consumption reduction by 70 percent compared to the typical ordinary building and existing building retrofits with 50 percent energy use reduction. Shanghai also incentivizes building retrofit on windows, exterior shading, and renewable energy integration, the use of three-dimensional design tool on green buildings, and energy management and service projects. The subsidy levels vary by projects, ranging from RMB 60/m^2 to RMB 100/m^2 for building area, RMB 150-250/m^2 for window area, RMB 30-200/m^2 for certified green area, and up to RMB 10 million one-time subsidy for large-scale demonstration projects.

The State Council released a *Green Building Action Plan* in 2012, setting a goal of at least 10 million square meters of new area of green buildings by 2015. The Action Plan also aims to have 20 percent of new buildings meet the green building standards. Financial incentives will be provided to the buildings certified as two-star and above in China's national green building system.

Distributed energy resources: In order to promote development of distributed generation, the National Energy Administration (NEA) issued a policy entitled *Distributed Power System Management* in 2011, which clarified the range of distributed power system, and provided subsidies to generating capacity or equipment based on new energy power generation such as wind power generation, solar power generation, biomass direct power generation or biomass gasification, biogas power generation, geothermal power generation and tidal power generation. In February 2013, the State Grid Cooperation announced its *Position on Providing Grid-Connection Services to Distributed Power Generation Systems*, which confirms this state-owned company's commitment to supporting grid connection by distributed power generation, including photovoltaic, natural gas, biomass, wind, geothermal, ocean tidal and wastes recovery systems. A related plan was also issued around that time setting a goal of 10 million kilowatt hours of distributed power generation. The government encourages the development of distributed power systems and building integration in China's central and eastern regions. The National Development and Reform Commission issued a *Notice on Improving Photovoltaic Power Generation Pricing Policy* in 2013. This document defines four types of solar resource area and sets corresponding feed-in tariff benchmarks. The tariff difference between grid-connected PV stations and local desulfurized coal-fired units will be compensated by a renewable energy development fund. The feed-in tariffs in the four areas range between RMB 0.75/kWh and 1/kWh.

Standards and codes

Building energy efficiency standards are mandatory in order to support the achievement of certain energy efficiency goals. They set specific requirements, such as a certain range for the area ratio of windows and wall, building shape coefficients, heat transfer rates for building envelope, and efficiencies of heating and air-conditioning. China's building energy codes and standards cover design, construction, inspection, operation and management phases, new and existing buildings, and residential and commercial/public buildings.

There are energy efficiency design standards respectively for commercial and residential buildings and for different climate zones. There are also *Inspection and Test Standards for Energy Efficiency of Residential Buildings*. Based on national standards, some local governments have also adopted higher standards according to local situations. Shanghai, Tianjin, Shenzhen, Jiangsu Province, and Zhejiang Province also implemented their own design and evaluation standards for "eco- demonstration zones" and green buildings.

To facilitate the compliance with building energy standards, the national government has published a number of technical guides, such as *Technical Rules for Enhancing Energy Conservation in Commercial Buildings, Technical Rules for Enhancing Energy Conservation in Existing Residential Buildings*, *Guidelines on Green Building Technology* (2005), *Evaluation Standards for Green Buildings* (2006), and *Guidelines on Green Building Construction* (2007). These guidelines explain the principles, general frameworks, key points, and appropriate technologies, equipment, and materials needed for seeking building energy efficiency or constructing green buildings. *Technical Rules on Green Building Evaluation* (trial), *Green Building Evaluation and Labeling System* (trial), and *Codes on Construction Quality of Building Energy Efficiency* provided further guidance.

Policy system development

As already mentioned in the previous sections, the Chinese government has established the country's own green building standards and certification system. China also has adopted its own building energy efficiency labeling system.

Other areas in which China has been developing its comprehensive policy systems are doors and windows. MoHURD issued a policy named *Management of Pilot Projects on Energy Performance Labeling for Doors and Windows* in 2006, and another entitled *Improving Energy Performance Labeling for Doors and Windows* in 2010. These policies require that in three years, all national scale manufacturers of doors and windows label the energy performance on their main products. Manufacturers are asked to improve their products' energy efficiency and building developers are asked to use labeled doors and windows in new buildings and when retrofit existing buildings. This year, MoHURD issued yet another document, entitled *Guidelines on Energy Performance Labeling for Doors and Windows*, which provides detailed steps on energy evaluation and labeling for doors and window.

MoHURD has been conducting annual evaluation of policy implementation since 2006. In that year, it organized a nation-wide inspection and evaluation on building energy efficiency efforts and heating system reform in cities. The evaluation looked at the implementation of various policies, regulations, technical standards related to building energy efficiency and heating system reform in 30 provinces excluding Tibet. It also randomly examined the implementation of mandatory energy standards in 610 projects. At the end of 2007, another round of inspection was carried out. This time the coverage was on building energy efficiency, heating system reform, municipal sewage plants, and household waste processing facilities and management. The latest result in 2012 (Ministry of Housing and Urban-Rural Development 2013) shows that most local governments further strengthened their leadership and coordination in carrying out building related energy efficiency work, especially in implementing the mandatory standards for new buildings and building retrofit. However, some problems were also revealed through the inspection, including some quality problems in building energy efficiency projects, wastes in energy consumption, and deviations from designed energy performance.

Part III. Conclusions and Recommendations

In conclusion, we first highlight the key advanced technologies that we believe offer significant energy efficiency potentials in the U.S. and China. We will then summarize the market barriers to their development and deployment, and finally make recommendations to China on how to help the advanced technologies penetrate the market.

Key advanced building energy technologies for China

Based on our review of emerging advanced building technologies in the U.S. and the current situation in China, we recommend the following key technologies for the Chinese building energy efficiency market.

Cool roofs

Cool roofs can have significant energy and peak demand saving potentials, ranging from 2 percent to 40 percent, for warmer climate zones. They are rarely used in China yet because of inadequate research. Based on available international technologies and experiences, China can initiate city level research and demonstration projects to study cool roofs' energy saving potential, technical feasibility, and cost effectiveness. From the results of these projects, China can develop a strategy for promoting the development of a range of new technologies.

Ground source heat pumps

While the application of GSHP has dramatically increased in China over the last few years thanks to the government's successful promotion and support, the utilization level of this shallow-depth, low-temperature geothermal resource is still very low compared to the huge energy available in the soil. To spur wider application of GSHP, the government should now place the emphasis on helping the GSHP market to further develop. In this context, the following factors are critical and requiring the government's policy support: 1) standardized product specifications and technical codes to ensure project quality and enhance investor s' confidence; 2) availability of financial assistance, e.g. loans and credits, to help project owners overcome initial high capital costs; and 3) clarity and consistency on regulations concerning water usage to facilitate GSHP project planning.

Lighting

As China is expected to continue its rapid urbanization in the next two decades, the already huge market for lighting will only grow more gigantic. Both consumer demand

and specialized demand (such as for roads, railway, airports, and industrial facilities) are big and keep growing. In 2012, the demand for incandescent bulbs still reached almost 1.2 billion, while the demand for straight and circle fluorescent tubes was 1.6 billion, for compact fluorescent lamps was 1.27 billion, and for halogen lamps was 755 million (Anonymous 2013). If LED lighting can replace a large portion of these demands, the energy savings will be enormous. Currently, LED takes less than 1 percent of China's lighting market, even though its growth has been in double digits (Anonymous 2013). The central government of China has recently taken major steps to encourage and support the development of China's own LED industry. This is a strategic right move. In parallel, it would need supplementary policies aimed at increasing market demand for LED, as fundamentally demand drives innovation and production.

Advanced power strips

Advanced power strips can save substantial amount of energy, as plug loads take around 20 percent of buildings' total energy use (a percentage that has been increasing with time). However, this technology has not been widely used in China, partly due to the higher prices than normal products and partly due to a lack of consumer awareness. Based on further market evaluation, China's responsible government agency can develop a public education program with an incentive package to promote its application.

Building energy management systems

BEMS is showing great potential in energy conservation if well programed and fully utilized. Currently, most building management systems in China are only for monitoring, with few intelligent control functions. With no diagnostic and analytical capabilities, Chinese commercial buildings can be consuming much more energy than they otherwise need for achieving the same levels of services. As many Chinese local governments are now aiming to build "intelligent cities", this is central technology for their goal, thus deserves governments' strong policy support in demonstration.

Demand response in buildings

Buildings that have the ability to control their HVAC, lighting, and other energy loads should have the ability to participate in demand response to help power grid disruptions and reduce the need for new power plant construction. Doing so will also cut energy costs—and even generate revenue—by lowering the peak demand and reacting appropriately based on price signals. In China, utilities have not started demand response programs yet, so building demand response technology and applications are very rare. However, demand response can help with grid stability, providing building owners not only with peak demand reduction but also cost savings. Therefore, we recommend that Chinese utilities consider starting demand response programs, and that the government support demand response development in China.

Integrated building design approach

Integrated building design is a critical step on the path to very low energy. Only integrated building design can harness efficiency synergies between systems and design processes to ensure that information on those systems is consistently collected and used for optimizing building operations.

Integrated design can lead to a building energy footprint that is 50 percent below the current ASHRAE standards through the following steps:

1. Obtain building owner buy-in.
2. Assemble an experienced, innovative design team.
3. Adopt an integrated design process.
4. Consider a day lighting consultant.
5. Consider energy modeling.
6. Use building commissioning.
7. Train building users and operations staff.
8. Monitor the building.

The importance of an integrated design approach has been realized by more and more actors in the building design industry in China. However, due to the restrictions of traditional design models, integrated design has rarely been used on a large scale. We recommend that the Chinese government develop informational and technical training programs to introduce this new concept to design organizations, encourage the use of such approach in its various demonstration projects, and establish a suitable model for the Chinese context. An effective policy to promote integrated design could be integrating into green building assessments, making integrated design an optional and measurable factor in the assessment process.

Market barriers in the U.S. and China

In China the biggest barrier to the promotion of building energy efficiency technologies is a lack of technology, information and experience. Other barriers, listed in order of importance, are: uncertainty about energy savings, insufficient return on investment, a shortage of funds, landlord / tenant differing incentives, and lack of awareness of energy efficiency.

In the United States, the primary market barrier to building technologies is a shortage of energy efficiency funds. An additional barrier is that building technologies generally cost more than decision makers' expect in terms of return on investment. Other barriers include an uncertainty of energy savings and a lack of building energy efficiency awareness and energy-saving technologies.

In addition, the policy and legal environment is an important factor affecting the use of advanced technologies to improve building energy efficiency in both the U.S. and China.

Recommendations for China

Design and update policies based on market diffusion theory

Market diffusion theory has been used to guide California's strategic path to zero net energy buildings (ZNE). According to this theory, different policy tools are identified and utilized targeting five different market penetration types: innovators, early adopters, early majority, late majority and laggards. For example, innovative financial tools and incentives are critical for innovators, who are ahead of the curve of market adoption, while mandatory codes are most effective for laggards on the road towards achieving ZNE. To help advanced technologies penetrate the market, China's building policy and incentive system can learn from the market diffusion theory by designing differentiated policy measures considering levels of subsidies, timing, target technologies, etc. There should be build-in mechanisms for timely impact assessment and policy revision at different development stages of the technologies.

Update building energy standards periodically towards very-low energy buildings

In the U.S., many building codes are strategically planned toward ZNE goals. For example, LEED codes were planned to evolve over time to gradually raise standards, with the goal of transforming platinum-rated buildings into ZNEs over the course of several code cycles. Similarly, California building codes, known as Title 24, are updated every three years with the goal of improving energy efficiency by at least 15 percent compared to previous cycle. In China, for historical reasons, building energy efficiency codes are based on percentage indicators (i.e. 30 percent, 50 percent, or 65 percent energy efficient). For the realization of very-low energy buildings or ZNEs, it is critical to set specific quantitative targets, such as K values for different parts of the building envelop, and to update codes periodically by tightening strengthening these targets. The switch from qualitative evaluation to quantitative evaluation, i.e. based on amount of energy consumed, will eventually lead to ZNEs in China.

Diverse incentive schemes to target different groups

China's building energy efficiency incentives are primarily provided to cities, large-scale developers, building owners or companies that carry out retrofits. Even though achieving energy efficiency improvements is a process that involves many stakeholders, no successful incentives simultaneously target different stakeholders. We recommend that China's decision-makers learn from US best practices and refine the current incentive policies in order to make them more concrete and pertinent. Take green building subsidies as an example; at present, a real estate developer alone may receive a subsidy for investing in green buildings, even though that developer alone cannot make an energy efficiency improvement happen. A building's design, construction and operation must all be green in order to achieve meaningful improvements. Therefore, incentives should also target design institutes, builders, and building operators. The experience in the U.S. has shown that providing incentives to these stakeholders can be very effective than only requiring them to comply with building codes.

Promote information transparency to help technological capacity building

As China is still rapidly developing, it naturally suffers from a lack of adequate technological expertise in terms of human and non-human capacities, e.g. skilled personnel, technologies, and management know-how. Such expertise will not be developed in closed-door efforts. Instead, information sharing and transparency is necessary for stimulating diverse collaboration, innovation in technology development and application, and eventually creating the demand for advanced building technologies.

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Appendix 1. Barriers to advanced building technologies and associated policy solutions

A. In the U.S.

Type of Barrier	Barriers	Technologies commonly facing this barrier	Policy solution	Case study example
Informational	Fragmented design and decision making process	Whole building	Integrated design-build process	NREL Research Support Facility
	Incomplete and imperfect information	Whole building	Energy labeling, technical assistance	Home Energy Rating, Green Proving Ground
	Unfamiliarity of architects, engineers, and building operators with new tech/products; lack of performance data thus new technologies often perceived as risky; lack of tools for simulating technology performance	HVAC, envelope, lighting, building controls, distributed energy resources	Workforce training, mandate monitoring and reporting for all new technology demonstrations, open access to energy modeling and simulation tools, technical assistance	DER-CAM, Energy Plus, FEMP, New York Times Building Upgrade, Green Proving Ground
Economic	High first cost of advanced technologies and designs	Many technologies	Financial incentives via technology or design subsidies	Savings by Design
	Lack of financing or access to credit	Whole building	Energy labeling	
	Lack of cost-recovery mechanisms		Decoupling of profits from sales	Decoupling in California and other states

	Split incentives	Whole building	Energy labeling, green leasing	Property Assessed Clean Energy
Regulatory	Code lock-in or prescriptive codes	Envelope, lighting, HVAC	Performance based codes	
	Interconnection charges for distributed generation	Distributed energy resources	Streamlined interconnection codes and procedures	IEEE 1547
	Lack of compensation for power/services sold	Distributed energy resources	Time of use pricing, net-metering, demand response payments	
	No incentive for lower emissions technologies	Distributed energy resources	Carbon price	AB32

B. In China

Type of Barriers	Barrier	Energy-saving technology aimed at by barriers	Policy recommendation
Information, awareness, knowledge	Energy-saving design and decision-making process is separated	Whole building	Integrate building energy-saving design, and planning energy-saving
	The info needed for decision-making is not complete	Whole building	Energy efficiency labeling, technological support
	Not familiarize the new energy-saving technology	HVAC, envelop structure, lighting, Building's auto-control system, distributed energy resources	Carry out training, mandate monitoring and report the new technological demonstration, simulated new technological tools are open to designers, technological support

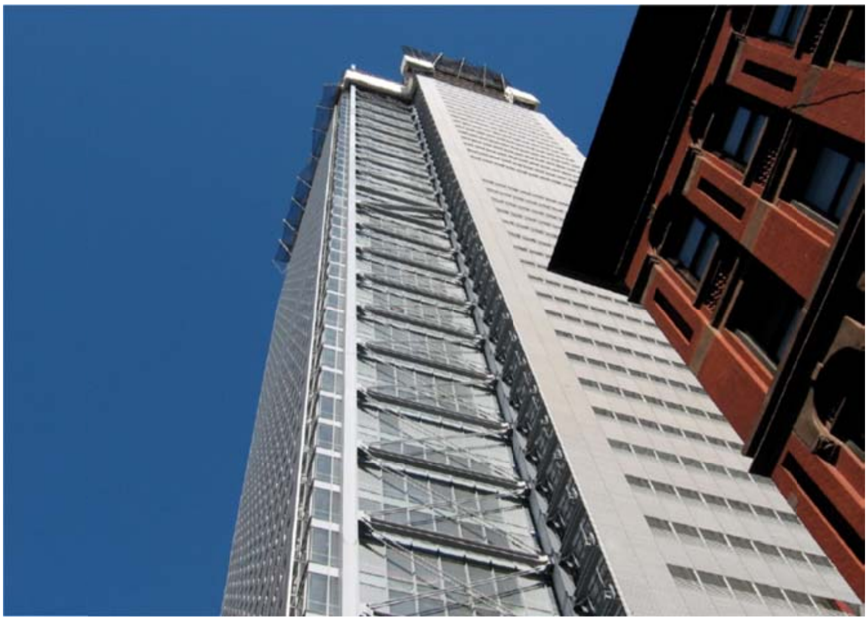
	The mode for energy-saving design is not calibrated, and still think the energy saving ratio, to some extent	Whole building, distributed energy resources	Calibrate the mode at design phase, check energy-saving based on actual quantity
	Energy-saving products' quality is various with short life span	Solar heating water, energy-saving doors & windows, lighting	Energy efficiency labeling, work out incentive policy at appropriate time
	General public is short of energy-saving awareness and knowledge	Multiple building energy-saving technology/ products	Mass media carry out the publicity campaign, NGOs organize special groups to publicize it
	Assessment standard is only based on adoption of energy saving tech, not on their economy	Green building	The standards should consider energy-saving and saving money integrated
Economical	Initial investment is higher or valued higher	Multiple energy saving tech and products for buildings	Compensation, tax credit; strengthen energy-saving for newly-built buildings
	Lack of finance and channel for loans	Integrated building, HVAC, distributed energy resources	Energy efficiency labeling, and economically, encourage users and utility companies
	Lack of the system for recovering funds		Decompose sales incomes
	Separated incentive	Integrated building	Energy efficiency labeling, green lease
	Contorted energy price system	Distributed energy resources	Carbon tariff
	Motivation for energy saving is not enough	Solar cell, integrated building	Choose proper players and targets for encouragement, change Compensation into returning tax, check actual

			things and quantity for energy saving
Management	Code lock-in or prescriptive codes	Envelop structure, lighting, HVAC, distributed energy resources	Standardize main property
	Complicated log-in procedures for distributed energy resources, with higher cost	Distributed energy resources	Rationalize log-in process
	Compensation for grid access tariff of distributed energy resources is not enough	Distributed energy resources	
	No Compensation for low emission technology.	Distributed energy resources	Carbon tariff system
	Property management level is low	HVAC, lighting system	Energy-saving efficiency demand, regular training for management staff, transition to facility management
	The related legal, specifications system and energy efficiency labeling are not completed enough	Distributed energy resources, energy saving retrofit for existing buildings	Improve legal clauses, allow grid access for distributed energy resources; work out price policy for grid connections; offer labeling of energy efficiency for each user

Appendix 2. A compendium of U.S. and Chinese cases utilized advanced building technologies

Demonstration case studies in the U.S.

New York Times Headquarters



A New York State Energy Research and Development Authority (NYSERDA) R&D investment with substantial cost share from The New York Times Company, the US Department of Energy (DOE), and the California Energy Commission Public Interest Energy Research (CEC PIER) program made possible the research needed to realize a set of efficiency features in the Times Building. Throughout that development process the Times Company staff shared design concepts, tested results, and commissioning processes widely in the New York community in a manner that has already impacted several other buildings. To further assist in promoting the benefits of energy efficient strategies the Times Company agreed to participate in a post-occupancy evaluation as a partner in the US Department of Energy's Commercial Building Partnership program. Together with the Lawrence Berkeley National Laboratory (LBNL) and the Center for the Built Environment (CBE) at the University of California, the Times Company has collaborated to conduct a monitored evaluation of three installed energy efficiency measures – dimmable lighting, automated interior roller shades, and an under floor air distribution system (UFAD).

A detailed, calibrated EnergyPlus building energy simulation model was then developed in order to derive annual total energy use. Occupant surveys were issued to evaluate user satisfaction with the workplace environment. The facility managers were interviewed to understand how maintenance and operations were affected by the systems. Over the course of this evaluation, the Times Company has deepened their understanding of how the installed energy efficiency measures performed while the project team has learned lessons that can be shared with the broader industry.

Item	Description
Technologies used	Integrated design practices Dimmable electronic ballasts and daylighting Automated interior shading Under floor air distribution system
Monitored energy savings	66,623 kWh/yr electricity 35,120 kBtu/yr natural gas
Actual costs savings	$13,081/yr
Project payback	8 years, IRR 12 percent
Barriers addressed	New unproven technologies with high risk High first cost and high labor costs
Policy and business solutions	Funding of third party field testing (LBNL) of measures prior to purchase Preassembled fixtures Commissioning by vendor

Hill Air Force Base study of GSHP

A feasibility study for a new proposed office complex at Falcon Hill Quad was performed to evaluate energy and cost savings potential by applying GSHP systems. The current proposed HVAC system for the building is a conventional VAV system with chiller and boilers. Although the proposed building already has numerous ECM features such as EIFS, water side economizer, high performance glazing systems, etc., the building also had a good potential to save further energy by applying a GSHP system. Funds were lacking to perform the upfront soil tests required, however, so the Federal Energy Management Program (FEMP) provided a small technical assistance grant to offset those costs.

The soil thermal conductivity test which was conducted in May, 2010 supports the feasibility by presenting favorable soil thermal conductivity and undisturbed underground soil temperature. The proposed GSHP system has 114 vertical boreholes (each borehole is 390 feet depth) and water-to-air heat pump systems to provide both space cooling and heating. The simulation result shows that there could be 2,428 MBtu of annual energy savings compare to the baseline building, which corresponds to 26.3 percent energy savings. The corresponding annual energy cost saving is estimated as $21,413. Since the capital cost for this GSHP system could be lower than the conventional VAV system with chiller/boiler, the immediate simply payback would be possible. The estimated greenhouse gas emission reductions from this application would be 21.6 tons annually. Therefore, the immediate simple payback and the $21K of annual cost savings suggest that this GSHP project is highly feasible for the given building.

Item	Description
Technologies used	Ground source heat pump
Monitored energy savings	2,428 MBtu/yr natural gas
Actual costs savings	$21,413/yr
Project payback	8 years, IRR 12 percent
Barriers addressed	Lack of tools/funding for simulating technology performance
Policy and business solutions	Use of laboratory/third party with government funding (FEMP) to perform a feasibility study

Isla Vista Case Study

As part of DOE's Commercial Building Partnerships program, the DOE partnered with Mesa Lane Partners to make a new, low-energy mixed-use building that consumes 50 percent less energy than ASHRAE 90.1-2007. Lighting energy efficiency measures accounted for half of the whole-building energy savings. A solar water heating system was used to preheat water to use in conjunction with a high efficiency condensing boiler. Because there was a project goal to offer affordable rents, minimizing first costs of energy efficiency measures was a primary criterion although the developer was open to measures with relatively short payback periods. When all systems were considered together and utility incentives taken into account, the payback period was 6.4 years.

The envelope design was key to reducing heating, ventilation, and air conditioning (HVAC) energy use. The envelope efficiency package by itself, without the associated reductions in HVAC system cost, did not make a compelling business case. However, the envelope efficiency measures were essential to the performance of the natural ventilation system, enabling the project to be built without air conditioning. The glazing was selected to reduce solar gain, and solar shading was incorporated in each unit. Phase-change material at strategic locations in the interior wallboards provided thermal mass benefits. Santa Barbara experiences a significant daytime temperature swing; in warmer summer months, the phase-change material can increase thermal mass during the cooler nights, which would last into the next day, providing an interior comfort benefit. The combination of these envelope measures made the natural ventilation scheme viable. It was through integrated design that these benefits could be realized.

Item	**Description**
Technologies used	Natural ventilation, lighting energy efficiency measures, solar shading and window glazing on façade, phase change materials, solar hot water
Expected energy savings	156,650 kWh/yr of electricity 2,934 MBtu/yr natural gas
Expected costs savings	$34,826/yr
Project payback	6.4 years
Barriers addressed	High upfront cost barrier Technology risk with natural ventilation and no-air conditioning in ensuring occupant comfort
Policy and business solutions	Integrated design Utility rebates

NREL Research Support Facility – Integrated Building Design

Demonstration cases in China

Energy-saving demonstration building by Ministry of Science and Technology#

The energy-saving demonstration building by Ministry of Science and Technology is situated at the southern side of Yuyuantan South Road, Haidian District, Beijing. It is a smart, energy-saving office building, put into use in 2005. This project is a state-level energy-saving and green demonstration project in the energy and environment-minded field cosigned by China-U.S. heads. The engineering cost per m2 is not over RNB 5200 Yuan, and won Innovation Award, class II, as the first nationwide green building in 2004; won a gold award for the lead energy-saving design issued by U.S. Green Building Society in 2005.

Energy-saving envelop structure: In between the two layers of hollow bricks placing a insulation layer made of foam polyurethane, insulated coated glass with low radiation, design light-colored exterior wall, use matte paint;

Natural lighting consideration: Use more daylight for lighting based on cross building body design;

Energy-saving lighting: Lighting control, infrared sensor + daylight sensor;

Energy-saving lift: The frequency changer system can be adjusted as per carrying capacity;

Heat recovery: Heat recovery device for ventilation and fresh wind;

Water-saving utensils: Non-water flush urinal;

Green roof: Air garden, all rain water is recovered;

Green building materials: No pollution; and their price is low;

Use renewable energy: Photovoltaic generation, solar heating water system, accounting for 9 percent of the energy consumption of the whole building.

The demonstration building increased investment RMB 4 million totally due to energy-saving and green design, however, after its operation, it can save water and electricity cost as much as RMB 0.7 million, it is predicted that the payoff period for this investment is 7 years.

The difficulties that will be met: initial investment is higher, and people would have doubt for the new energy-saving technology.

How to solve them: The lower loads brought by effective building envelop structure reduce the investment for air-condition equipment, thus, their total investment does not increase too much.

Shenzhen Jianke Building

Shenzhen Jianke Building is the office building of Shenzhen Building Research Institute which was put into use in April, 2009 as a demonstration platform for United Nation Development Program (UNDP) with low-energy consumption and green building integrated technology. It was the first national renewable energy demonstration project, and obtained "The National Green Building Innovation Award" in 2011. Aimed at exploring low cost and soft technology to implement green building pattern, the building adopted a series of over 40 appropriate technologies from design to its construction in order to reach greatest potential of cost saving and efficient resource utilization within its life-span, so as to protect environment and reduce pollution. Among those technologies, passive designs, low- cost technology, and management technology accounts for 68 percent, which included:

Building envelope structure: XPS inverted roof with thermal insulation, ECP side fascia + interior insulation, aerated concrete block and heat retaining board, low-E hollow glass, photoelectric curtain wall (southwest facade), sunshade reflecting board (other three facades);

Green energy-efficient lighting: LED source, infrared induction ceiling lamp (self-extinguishing type), lamp T5, and intelligent lighting control;

Heat recovery: exhaust air heat recovery, frequency conversion for water system and fresh air cooling in transition season;

Energy management system;
Renewable energy utilization: Solar hot water system, single crystal silicon photovoltaic cell structure, BIPV, and polycrystalline silicon solar module, hot water generated by solar energy accounts for high proportion that over 50 percent and electricity generated by PV module accounts for 5-7 percent of entire electricity consumption of the building;

Water-saving: Rainwater collection, reclaimed water treatment, water-saving appliances, constructed wetland sewage treatment system;

Natural ventilation design: The layout resembles Chinese character "吕(pronounce lv)" which has certain misplacement between east and west, which create a design for natural lighting ;

According to estimation, annual operating costs can be reduced by RMB1.5 million Yuan, electricity saving is RMB1.45 million Yuan in comparison of those of conventional building, water saving is RMB 54 thousand Yuan, standard coal saving is 610 tons, and emissions of carbon dioxide can be reduced by 1600 tons.

Jianke Building has been open to public and allowed to be visit after being put into use, and it brought a good demonstration effect and social benefit. It showed that a green building does not always mean high prices and high costs, take this building for a good example, only RMB 4000 Yuan per square meter, and its significance is well reflected and worthy to be spread to build such energy-saving eco-office with regional characteristics at low cost.

Shanghai Chongming ecological building for demonstration

Chongming Ecological Building is located at Chenjia Town, Chongming, Shanghai. It was a key scientific research project of Climb Plan issued by Science & Technology Commission of Shanghai Municipality in 2006, and was completed and put into use in 2009.

The project was listed into the national and Shanghai municipal green building projects, and was selected as a major science and technology demonstration project of national "The 12th Five-Year Plan" for habitat environment. In 2013, it was entitled as “The National Green Building Innovation Award”.
Sticking to sustainable development in its design, emphasizing on low carbon emission, energy-saving, pollution reduction and resources recycling, it combined advanced technologies of domestic and foreign countries for green building which included:

Energy saving envelope structure: concrete hollow bricks + expansion of Polystyrene (EPS) for external thermal insulation, extruded polystyrene (XPS) for roof insulation + sloping ceramsite concrete, double low-E hollow glass + insulating aluminum profiles, shading technology;

Natural lighting consideration: opening area of windows of south facade is greater than 50 percent, active lighting measure -light pipe;

Natural ventilation: ventilation tower, wind guide wall;

Energy-efficient lighting: coordinating natural light and artificial light and with the use of adjustable lighting, saving about 30 percent of energy consumption than that of the traditional way of lighting;
Green building materials: no pollution with low price;

Renewable energy utilization: solar power systems, wind power generation system;
Air system: ground source heat pump air-conditioning system, capillary radiation and independent dehumidification air system, personalized fresh air technology;

Smart control system: Interior environmental quality control, energy-saving control for lighting system, air conditioning system monitoring and renewable energy monitoring;

Water-saving: biological sewage treatment, reclaimed water treatment, roof rainwater recycling for landscape water;

Energy saving rate of Chongming Ecological Building complex is more than 75 percent, renewable energy utilization rate is more than 50 percent, and renewable resource utilization rate is greater than 60 percent. Zero energy consumption (annual capacity for new energy equals to its annual consumption) and zero emissions (recovery measures were taken to reuse inorganic wastes like waste papers, waste plastics and to recycle domestic organic waste) can be basically achieved during its operation. Technologies applied in Chongming ecological building can be taken into consideration for Chongming ecological human habitat construction and can be referred to promote ecological planning, construction and operation management for Chongming ecological island.

International Environmental Convention Building

International Environmental Convention Building is located in Xicheng district, Beijing City. It was constructed with the international free aid funds by Foreign Cooperation Center of Ministry of Environmental Protection. The project was commenced in March, 2007 and completed in May, 2009. The project was accepted as green building demonstration project by National Ministry of Housing and Urban-Rural Construction In 2010, and at the same time it was certified as three stars green building. In 2013 it obtained First Prize of "The National Green Building Innovation Award". The construction of the building was abided by concept of sustainable development with many practical energy-saving technologies to reflect its demonstration effect which included:
Energy saving envelope structure: new pattern thermal insulation materials for side fascia, hollow low-E glass and heat isolation technology for glass curtain wall, and aluminum honeycomb composite marble slabs for exterior curtain wall, shading technology.

Energy-saving lighting: digital smart lighting system, automatic solar incidence line tracking system, skylight;

Renewable energy utilization: solar photovoltaic generation, solar water heating system;
Water-saving: rainwater collection and infiltration recharge, reclaimed water treatment, water-saving appliances;

Natural ventilation: auto ventilation shutter control at the top of atrium;
Heat recovery: exhaust air heat recovery, frequency conversion for water system and fresh air cooling in transition season;

Green building materials: no pollution with low price;

Air conditioning system: independent temperature and humidity control, chilled beams;

Smart building control system: intelligent lighting system, elevator operation management system, air conditioning intelligent operation system, automatic control system of water supply and drainage;

The building is a useful attempt by Sino-Italy environmental departments and designers to fulfill "green, low carbon" construction, and it is an exploration for the best practical technology. By adjusting its design and construction to fit for local conditions, putting passive measures into priority, and with comprehensive utilization of green building strategies and optimal high-tech which are suitable for construction in Beijing , the building reached objective of land saving, energy saving, water saving and material saving. Its success plays a certain demonstration role for feasible technologies selection in building energy-efficient green office type projects in Beijing area.

Green Demonstration Building of Logistics Engineering College

Green Demonstration Building of Logistics Engineering College is located at southwest corner of the new campus of Chongqing Logistics Engineering College. As the first green building demonstration project of Chongqing, it started construction in January, 2010, and was completed in August and put into use in Sep, 2011. The design of the project has been certified by LEED-NC of the United States Green Building Commission and also been listed into demonstration project of National Hundred Green Buildings by Ministry of Housing and Urban-Rural Development in June, 2009. In February, 2013, the Building Department accepted its completion and in March, 2013 it was entitled with the First Prize of “The National Green Building Innovation Award”. The building took more than 20 measures for green construction which included:

Energy-saving envelope: aerated concrete bricks + 30 cm thick polyurethane heat insulation board for side fascia, heat reflective paint for exterior wall decoration, hollow aluminum alloy window frame + double hollow low-E glass for windows, “breathable” double glass for parts of south façade of the glass curtain wall, vertical container greening is designed for the certain parts of wall between windows faced to the south facade, shading technology, green roof;

Renewable energy application: solar photovoltaic generation, solar water heating system; ground source heat pump as the heat and cold source of air conditioning system;

Natural ventilation: ventilation shaft and ventilation ducts;

Natural lighting: reflector board, lighting well, optical fabric and relay;

Air-conditioning system: ground source heat pump system as the heat and cold source of air conditioning system, CO2 density monitoring, frequency conversion for water system and fresh air cooling in transition season;

Heat recovery: fresh air and exhaust air heat exchanger;
Energy-efficient lighting: Energy-efficient lamps, intelligent lighting control mode with the method of local lighting and accent lighting;

Water-saving: rainwater recycling, treatment and reuse of grey water, water-saving appliances, base water conservation;

A smart building: building safety alarm system, equipment operation control system, energy consumption metering system;

The measured data based on annual operation shows that energy-saving rate is 79 percent, water-saving rate is 58 percent, non-traditional water using rate is 37 percent, and carbon dioxide emissions can be reduced by 2174 tons with annual saving 828 tons of standard coals. The incremental cost is RMB 475 Yuan / square meters, and in accordance with the actual operation data calculation, incremental cost can be recouped in 6.8 years. Its economic and ecological benefit is obvious; the project shows that green concept on development has been practiced by the municipal people and the troops, and it is a good setting and an important carrier to exhibit and communicate results of utilizing green building technology.